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VENUS in the SUN:

BEING AN
EXPLICATION of the RATIONALE
OF THAT
GREAT PHÆNOMENON;
OF THE
Several METHODS uſed by ASTRONOMERS for Computing the QUANTITY and PHASES thereof;
And of the Manner of applying a
Tranſit of VENUS over the SOLAR DISK,
For the DISCOVERY of the
PARALLAX of the SUN;
Settling the THEORY of that PLANET'S MOTION, and Aſcertaining
THE
DIMENSIONS of the SOLAR SYSTEM.

By BENJAMIN MARTIN.

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7

BRITISH MUSEUM

THE

PREFACE.

I T is now twelve Months ſince I firſt publiſhed a Commentary on Dr. HALLEY'*s Diſſertation on the* TRANSIT OF VENUS, *in the* General Magazine of Arts and Sciences; *but being often importuned to publiſh that Treatiſe in one entire View, I at length concluded to do it, but not without conſiderable Alterations and Additions thereto. For though the Doctor's Performance was a Maſter-Piece in its Kind, yet there is another, and, perhaps, the moſt genuine Method of Computing the Quantity, Phaſes, and various Affections of the* TRANSIT, *which has not, that I know of, been ever explained in* Engliſh; *and therefore I have here attempted it, for the ſake of ſuch as may be willing to know the moſt direct and Aſtronomical Method of Computation; I mean that of* PARALLAXES; *the Theory of which I have laid down in the plaineſt Manner I could, and have exemplified the ſame by adapting the* Calculus *to the End of the Tranſit, as it will be obſerved here in* England.

I am well ſatisfied, neither the Doctor's Method by Projection, *nor this other by* Parallaxes, *can be well underſtood, without a proper Idea of the Theory of this Planet; which therefore I have ſupplied, and by that means the Rationale of Calculation will be more intelligible.*

After this you will find the Uſe of Tranſit for aſcertaining the Elements of the Theory of *Venus*'s Motions, *according to the Method of Parallaxes uſed by Mr.* HORROX *and Mr.* CASSINI, *exemplified in the Tranſit of* 1639, *now firſt done into* Engliſh.

I have alſo added an Account of the Motion of the Nodes of Venus, *as I find it in all the Tables hitherto publiſhed that I have ſeen, in or-*

der that the Reader might have a proper Notion of ſo fundamental a Principle.

As to the Geographical Principles *of the Tranſit, I have illuſtrated them by the Uſe of the* Terreſtrial GLOBE, *as a neceſſary Introduction to the whole. Nor is the Uſe of the* Celeſtial GLOBE *inconſiderable, as thereby any Perſon, curious in theſe Matters, may eaſily attain to a practical Method of determining the Angle* E S Z *(ſee Figure* 3 *and* 4. *Plate* III.), *made by the Circle of Latitude* E R, *and the Vertical* C S N, *by which means the Poſition of the* ECLIPTIC T L *will be obtained, and thereby a Repreſentation of the ſolar Diſk formed as large as you pleaſe for any given Place and Moment of the Tranſit; by this means alſo the ſeveral* Phænomena *of the Tranſit may be eſtimated by the* Scale and Compaſſes; *and a* Heliometer *adjuſted for meaſuring the Diſtance of the Planet from the Ecliptic, at any Moment of her Paſſage.*

INTRODUCTION,

SHEWING

The USE of the TERRESTRIAL and CELESTIAL GLOBE in exhibiting the various Phænomena of the TRANSIT of VENUS.

AS I conceived the moſt familiar and general Way of exhibiting the various Phænomena of a Planet tranſiting the Sun's Diſk, is by means of the artificial Globes, I ſhall here briefly deſcribe that Method, by way of Introduction to Dr. HALLEY's Diſſertation, and what afterwards follows.

In order to this, we firſt conſider the Place of the Sun in the Ecliptic, and his Declination for the middle Time of the Tranſit, and then, by rectifying the Globe, we can eaſily ſhew all thoſe Places of the Earth where the Beginning, the Middle, and End of the Tranſit can be obſerved, and at what particular Times of the Day; as alſo how, by the different Directions and Motions upon contrary Parts of the Globe, the Times of the Tranſit will be affected, ſo as to be in ſome Places longer, and in others ſhorter; and laſtly, what Poſition the Ecliptic will have in regard to a vertical Circle for any given Place, and of courſe what the Poſition of the Path of the Planet will be, in its Paſſage over the Sun for that particular Place; all which together will conſtitute a general Idea of this great and moſt intereſting Phænomenon.

The Place of the Sun in the Ecliptic, when the Planet *Venus* will be ſeen to enter his Diſk, is in 15° 30′ of *Gemini*, and of courſe his Declination will be near 22°; and therefore if the Globe be rectified for that Parallel of 22° Latitude, then will it be in a Condition to exhibit all the Appearances of the Tranſit. This we preſume the Reader knows muſt be done by elevating the North Pole 22° above the North Part of the Horizon.

The Time (reckoned at LONDON) of the Beginning of the Tranſit we find, by Dr. HALLEY's Tables, is about Five Minutes after II. in the Morning, on the Ninth Day of *June* next; the true Conjunction, or rather Middle of the Tranſit, will be about half an Hour after V.; and the End about three Quarters after VIII. So that the whole Duration will be little more than ſix Hours and a half.

Now to ſhew all the Places on the Globe to which the BEGINNING will be viſible; you bring the Place (LONDON, for Inſtance); to the Meridian (having rectified the Globe as above directed) and then place the Hour-Index at the Hour of II. in the Morning; then turn the Globe about till the Index points to XII. at Noon, and the upper Hemiſphere will then be that only, in which the Beginning of the Tranſit can be ſeen; where you will obſerve that all thoſe Places which lie under the Meridian, will ſee *Venus* enter the *Sun*'s Diſk upon the Meridian at XII o'Clock. But theſe will be very few; *viz.* The Eaſtern Parts of *Muſcovy*, and *New Britain*, near the Equator; the *Great Pacific Ocean* almoſt wholly occupying the Meridional Parts of the Globe. And here it is to be obſerved, that the *Sun* is vertical at that Time to the moſt Northern of thoſe Iſlands called the *Ladrones*.

In the next Place, you obſerve all the Places of the Globe lying under the Weſtern Semicircle of the Horizon; for to them the *Sun* will be then riſing; the Reaſon of which is evident, becauſe the *Sun* being over the middle Point of the Hemiſphere above the Horizon, will illuminate the ſame throughout; and the wooden Horizon of the Globe is now, properly ſpeaking, the Solar Horizon; and the general Meridian, in which the *Sun* is, becomes the Horizon to all thoſe who lie under the Weſtern Horizon of the Globe. Theſe Countries, by the Motion of the Globe, are juſt entering into the illumined Hemiſphere, and ſee *Venus* entering the *Sun's* Diſk, juſt riſen above their Eaſtern Horizon. Theſe Countries, you will obſerve, are *Norway* and *Sweden, Poland,* the *Black Sea,* and all the middle Part of *Turky* in *Aſia*; after which, to the Southern Parts of the Meridian, you ſee nothing but the *Great Eaſtern Ocean*.

From hence it follows, that all in that Quarter of the Globe which lieth between the Weſtern Horizon and the Meridian, will ſee the Beginning of the Tranſit ſome time in the Morning, or Forenoon, and later in Proportion as they are nearer to the Meridian, at the rate of an Hour to every 15° in the Equator. So that from hence it will be very eaſy to know, by Inſpection, the Hour of the Morning when this Phænomenon can be obſerved; becauſe, on *Senex's* twelve-inch Globes, the Meridians are real Hour-Circles, being drawn through every 15° of the Equator, and conſequently are 24 upon the Whole. You then caſt your Eye on the Eaſtern Semicircle of the Horizon, and under that you ſee but a ſmall Part of the inhabited Globe, *viz. Hudſon's Bay*, the Weſtern and South-Weſt unknown Parts of *North America*, and Southern Parts of *California*. If they have ever heard of the Tranſit, and have any Means of viewing the *Sun*, they will ſee the Planet enter his Diſk juſt as the *Sun* is ſetting, becauſe at that Inſtant they are, by the Motion of the Globe, carried Eaſtward out of the enlightened Hemiſphere.

It is very remarkable, that all this Quarter of the Globe, between the Meridian and Eaſtern Horizon, is covered with Water, except ſome of the unknown Parts of *America*, extending towards *Muſcovy*; and therefore it is probable the Beginning of the Tranſit will not be obſerved in the Afternoon any-where, unleſs by thoſe who navigate the *Great Pacific Ocean*.

It is further to be obſerved, that all the Parts of the World which lie on the nether Hemiſphere, cannot ſee the Beginning of the Tranſit; among which, below the Weſtern Horizon, near the North, you will obſerve our Iſland of *Great Britain*, great Part of *Europe*, all *Africa*, and almoſt all *America*. Thus much for the BEGINNING of the Tranſit.

In the next Place, to exhibit the Phænomena for the MIDDLE of the Tranſit. The Globe remaining rectified as before, you bring the City of *London* to the Meridian, and there holding it firmly, you ſet the Hour-Index to half an Hour paſt V. in the Morning, and then revolve the Globe till the Index points to the Hour of XII. at Noon; and thus you will have in View that Hemiſphere of the Globe in which the MIDDLE of the Tranſit can be ſeen, *viz.* all above the Horizon. And to thoſe who inhabit the Hemiſphere below, which are, nearly, all the Parts of *America*, and the Weſtern Parts of *Africa*, the Middle of the Tranſit will not appear.

From what we have ſaid before, it is evident, that to all the Parts of the Globe which now lie under the general Meridian of the illumined Hemiſphere, *Venus* will appear in Conjunction with the *Sun* at XII o'Clock. Theſe are all the Midland Parts of *Aſia*, from the Northern Parts of *Muſcovy* to the *Eaſt Indies*, near which you will ſee *Bencoolen*, in the Iſle of *Sumatra*.

In the Weſtern Hemiſphere you will obſerve all the Countries in the Weſtern Semicircle of the Horizon to which the *Sun* will riſe, with *Venus* advanced to the middle Part of her Path over his Disk. Theſe are only the Weſtern and Southern Parts of *Africa*. In all this Quarter between the Weſtern Horizon and the Meridian, the Middle of the Tranſit will be ſeen in the Forenoon, earlier or later, as the Places are more remote, or nearer to the Meridian. Among theſe you will obſerve our Iſland at a ſmall Altitude above the Horizon, having been *riſen* (as one may ſay) into the illumined Hemiſphere but one Hour and half.

By turning the Eye to the Eaſtern Semicircle of the Horizon, you will find nothing but the *Great Pacific Ocean* lying under it, excepting a ſmall Portion of the undiſcovered Parts of *North America*, and ſome Parts of the Coaſt of *New Zealand*, in Southern Latitude. It is therefore probable that the Middle of the Tranſit will be no-where obſerved at Sun-ſet; but in all the Countries in this Quarter of the Globe it will be ſeen at ſome time or other in the Afternoon, and to moſt of them before IV o'Clock.

In the laſt Place, for the END of the Tranſit, which is at Three-quarters after VIII. in the Morning, we muſt rectify the Globe for that Time; that is, bringing *London* to the Meridian, you muſt ſet the Hour-Hand to that Time, and then revolve the Globe till it points to the upper XII. and you will have preſented to your View that Hemiſphere of the Globe in which only the *End of the Tranſit* can be ſeen.

To all the Countries that lie under the Meridian, *Venus* will appear to go off from the *Sun's* Disk at Noon. Theſe are all the Eaſtern Parts of *Ruſſia*, the *Caſpian Sea*, the Weſtern Part of the Kingdom of *Perſia*, and the Eaſtern Parts of *Arabia*, with the North Part of the Iſland of *Madagaſcar*.

In the Weſtern Semicircle of the Horizon you ſee thoſe Countries where the End of the Tranſit will appear at Sun-riſing, among which are the Eaſtern Parts of *Hudſon's Bay*, in *North America*; *North Britain*, *Nova Scotia*; and a ſmall Tract of the Eaſtern Parts of *Brazil*. In this Quarter of the Globe, among thoſe who ſee the End of the Tranſit in the Forenoon, you obſerve the whole Continent of *Africa*, the greateſt Part of *Europe*; our Iſland in particular, in North Latitude,

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The TRANSIT of VENUS over the SUN'S DISK
June 6. 1761.

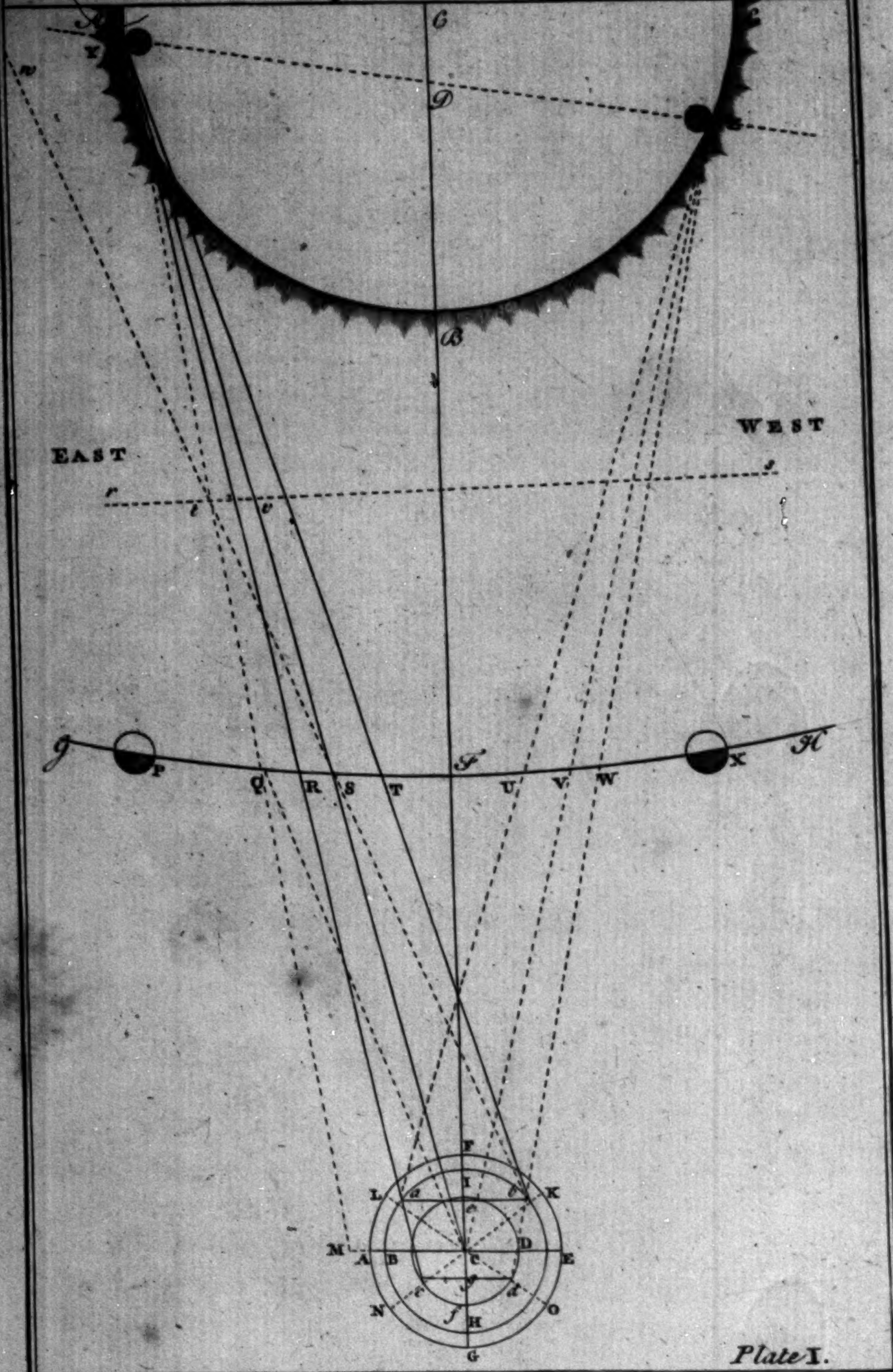

Plate I.

titude, and St. *Helena* in the South, viewing this Phænomenon nearly at the ſame Time of the Day.

In the Eaſtern Semicircle of the Horizon you ſee a few Countries lie; but moſt of them unknown to us; and probably not an Inhabitant among them all will ſee *Venus* make her Exit from the *Sun's* Disk at his ſetting. However, a great Part of the World, the vaſt Continent of *Aſia*, will have the Pleaſure of viewing this critical Phænomenon ſome Time in the Afternoon, if the Weather prove favourable to them.

Thus you proceed to find the various Appearances of the Tranſit for any other Place, as well as *London*. Having firſt obſerved the Difference of Longitude between the Meridian of *London* and the given Place, and converted it into Time, by which Means the Times of the Beginning, Middle, and End of the Tranſit become known, and the various Appearances repreſented for that Place, in the ſame Manner as we have now done for *London*.

The diurnal Motion of the Globe being in a Direction from Weſt to Eaſt, and that of *Venus* over the *Sun's* Disk being the contrary Way, from Eaſt to Weſt, will cauſe her to be ſeen a leſs Time on the Surface of the *Sun*, than ſhe would have appeared if the Earth were at reſt; or if ſhe was viewed only from the Earth's Center, which is at reſt with Reſpect to the ſuperficial Parts; for in either of thoſe Caſes, we ſhould ſee the true and real Motion of *Venus*. Whereas now, as we are moving towards the Planet, or to meet it, the Time of the Beginning or End of the Planet will neceſſarily be contracted. And this will be the Caſe of all the People that live in ſuch Parts of the Earth where the Beginning and End can be obſerved, as at *Bencoolen*, in *Sumatra*; and all other Parts of the *Eaſt Indies*. But as every Place, while it deſcribes the nocturnal Part of its Parallel, has a different Direction of Motion from that in the diurnal Part with Reſpect to a diſtant Point in the Heavens, ſo thoſe Motions in the nocturnal Parts of the Parallels will have the ſame Direction as the Planet *Venus* itſelf; and conſequently ſuch as are in a Situation to view the Beginning and End of the Tranſit, while they deſcribe their nocturnal Arches, will have the Duration of the Tranſit thereby prolonged; for if we move the ſame Way with another Body in Motion, that Body will appear to move more ſlowly than it would do if we ourſelves had no Motion at all.

Now if we ſuppoſe the Planet *Venus* were to traverſe the ſame Diſk ſo near the *Sun*'s Center as Dr. HALLEY, in his following Diſſertation, has ſuppoſed, then her Path over the *Sun* would be conſiderably longer than Six Hours and a Quarter, before-mentioned, *viz.* almoſt Eight Hours; which would have given an Opportunity for obſerving the Beginning and End of the Tranſit by Perſons moving in both the above-mentioned Directions, *viz.* Thoſe of the *Eaſt Indies*, the contrary Way to the Planet, and thoſe at *Fort Nelſon* (at the Mouth of *York River*, at *Hudſon's Bay*, in *North America*) moving the ſame Way with the Planet; for then thoſe latter Obſervers at *Fort Nelſon* would not only have obſerved the Beginning of the Tranſit at Sun-ſet, but likewiſe the End of it at Sun-riſing; and thereby have obſerved a Duration of the Tranſit much greater than thoſe in the *Eaſt Indies*, as you may eaſily ſee by rectifying the Globe, as before directed, for the Hours of II. in the Morning, and Three-quarters after IX. for the End.

But there is great Reaſon to ſuppoſe (as we ſhall hereafter ſhew) that by reaſon of the Motion of *Venus*'s Nodes, ſhe will be carried much lower on the *Sun*'s Surface, and thereby the Time, both at the Beginning and End of the Tranſit, will be contracted; and though not enough, at the Beginning of the Tranſit, to render it inviſible at *Fort Nelſon*, yet the End of it at Three-quarters after VIII. will be ſo much earlier than before, that *Fort Nelſon* will not have reached the Weſtern Horizon at the Time that *Venus* departs from the *Sun*'s Disk at her Riſing; all which is plainly obſerved from the Globe rectified as before-mentioned for thoſe particular Times.

Since the Doctor's Diſſertation is to ſhew how the *Parallax*, and conſequently the *Diſtance*, of the *Sun* from the *Earth*, may in a great Degree be aſcertained from the Difference between the true and apparent Duration of the Tranſit, it follows, that if the Beginning and End of the Tranſit could have been obſerved at *Fort Nelſon* as well as at the *Indies*, that then this Diſcovery could have been made to that Degree of Exactneſs which the Doctor propoſes; *viz.* to within at leaſt a five hundredth Part of the whole. But as the Caſe is now like to prove, the apparent Duration by its Contraction only at the *Indies* will have a leſs Difference from the true Time, and therefore we muſt be content, at preſent, with a leſs perfect Determination of the *Sun's* Parallax than we were at firſt in Expectation of.

But as another Tranſit of the ſame Planet, at the ſame Node, will happen in the Year 1769, on the 3d of *June*, which would have proved of little or no Service to us, had the preſent Tranſit been ſuch as we firſt expected; yet, in Proportion as this is rendered more deficient for anſwering the propoſed Diſcovery, that will be made more ſubſervient to it; and, indeed, will fully anſwer all that can be expected from a Tranſit, and leave nothing more to be hoped for. So that, upon the Whole, we ſhall have two Tranſits, by this means, inſtead of one; and if we make the beſt Uſe of each, there is no doubt but Aſtronomy will, in ten Years Time, attain to its ultimate Perfection. But of this Subject, and more particularly of the Tranſit in 1769, we may take another Opportunity of diſcourſing more at large.

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A PROJECTION and CALCULATION of the TRANSIT of VENUS.

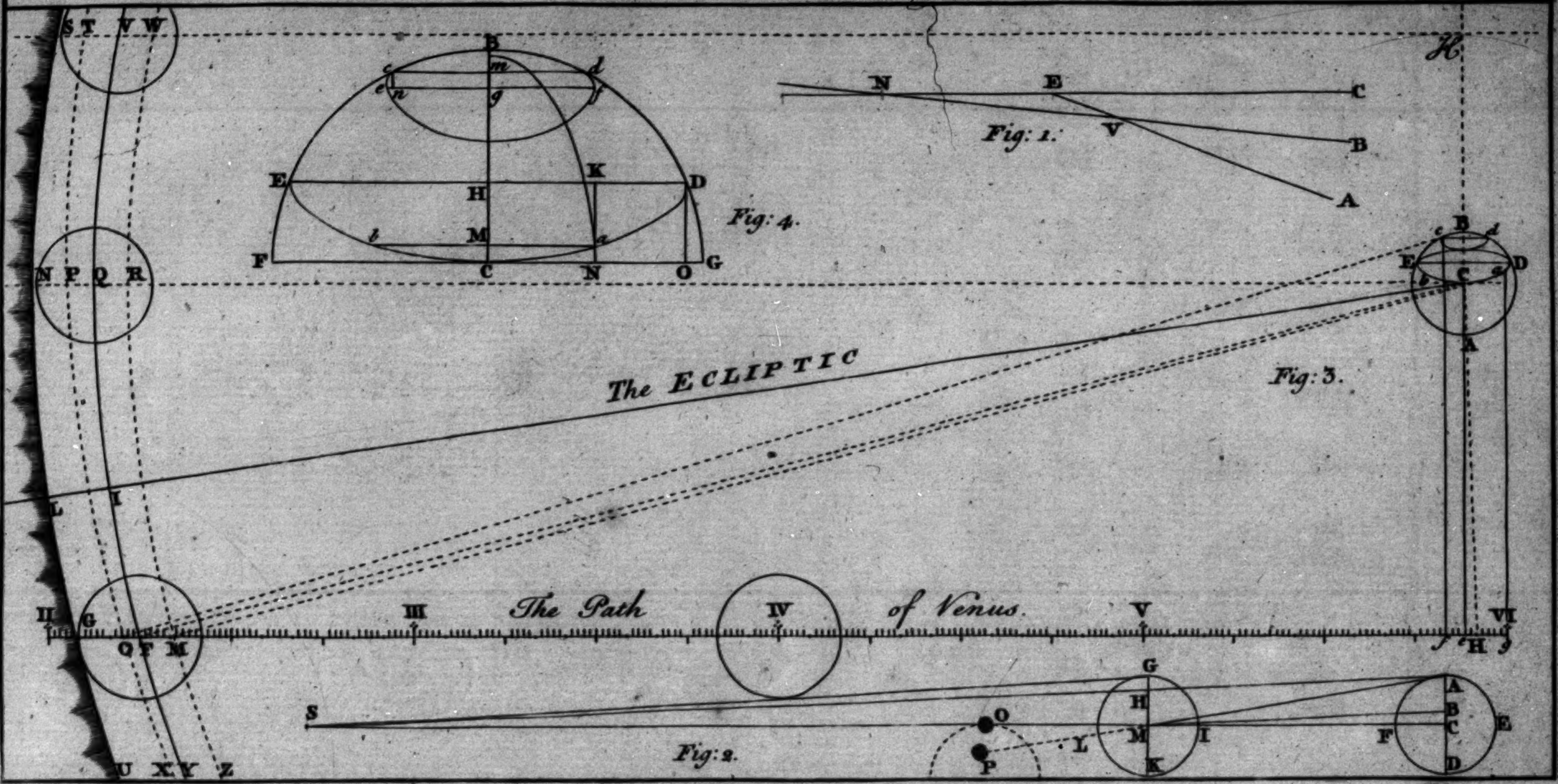

Plate II.

Dr. HALLEY's DISSERTATION

On the METHOD of Determining the PARALLAX of the SUN

BY THE

TRANSIT of VENUS, JUNE 6. 1761.

N. B. *This Diſſertation was delivered to the* Royal Society, *and publiſhed in their Tranſactions*, N° 348.

I. NO Problem ſeems of a more difficult Nature than that which is propoſed, to determine the Diſtance of the *Sun* from the *Earth* near the Truth; which yet, from proper Obſervations [*], obtained at particular Times and Places, may be ſolved without much Labour; and what I now propoſe to this Society is, to ſhew our [†] young Aſtronomers (who may live to make thoſe Obſervations) a Method [‡], by which they may meaſure the immenſe Diſtance of the *Sun*, within the 500th Part of the Whole.

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[*] The Obſervations here referred to are thoſe which are to be made on the Tranſit of *Venus* over the Face of the *Sun*, in the Year 1761, at the *Eaſt Indies* on one Part, and at *Hudſon's Bay* on the other, as is more fully declared in the Sequel of this Diſſertation.

[†] The Doctor had Reaſon to mention *young Aſtronomers*, becauſe at the Time he wrote this, which was about the Year 1718, the Tranſit of *Venus* was at the Diſtance of 43 Years.

[‡] The Method propoſed by the Doctor for this Purpoſe is the Subject of this Diſſertation, *viz*, The Difference of the Times of the Tranſit of *Venus* over the *Sun*'s Diſk, obſerved from the two diſtant Parts of the *Earth* before-mentioned. The Doctor, who is on all hands allowed to be the greateſt Judge in thoſe Things, has given very good

II. It is well known that this Diſtance of the Sun from the Earth is ſuppoſed different by different Aſtronomers; *Ptolemy* and his Followers, as alſo *Copernicus* and *Tycho Brahe*, have computed it at 1200 Semi-diameters of the Earth; *Kepler* at almoſt 3500; *Riccioli* doubles this laſt Diſtance, and *Hevelius* makes it only half as much *.

III. But at length it was found, upon obſerving by the Teleſcope, *Venus* and *Mercury* on the *Sun*'s Disk, diveſted of their borrowed Light, that the apparent Diameters of the Planets were much leſs than hitherto they had been ſuppoſed to be; and in particular, that

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Reaſons why the Planet *Mercury*, ſeen in the *Sun*, will not afford ſo good an Opportunity for determining the *Sun*'s Parallax as the Planet *Venus*; concerning which, in a former Diſſertation (ſee *Tranſ.* N° 193.) as well as in the preſent, the Doctor ſpeaks of the Tranſit of *Venus* as that by which alone this great Point can be obtained. This Sight, ſays he, which is by far the nobleſt that Aſtronomy affords, like the Secular Games, is denied to Mortals for a whole Century by the ſtrict Laws of Motion; it will be afterwards ſhewn, that by this Obſervation alone the Diſtance of the *Sun* from the *Earth* may be determined with the greateſt Certainty, which, on account of the Parallax otherwiſe intirely inſenſible, hath not hitherto been preciſely defined; and at the Concluſion of that Number, he hath this remarkable Paragraph:

The principal Uſe of theſe Conjunctions is accurately to determine the Diſtance of the Sun *from the* Earth, *or his Parallax, which Aſtronomers have by ſeveral Methods attempted in vain, whilſt the Smallneſs of the Angles ſought, does eaſily elude the niceſt Inſtruments; but in obſerving the Ingreſs of* Venus *into, and Egreſs from, the* Sun, *the Space of Time between the Moments of the internal Contacts may be obtained to a Second of Time; that is,* $\frac{1}{15}$ *of a Second, or* $4'''$ *of the obſerved Arch, by Means of an ordinary Teleſcope, and Clock that goes accurately for ſix or eight Hours.*

* The Methods by which the above-mentioned Aſtronomers attempted to determine the Parallax of the *Sun* may be ſeen at large in their Writings, or in the Aſtronomical Lectures of Mr. *Whiſton*, Dr. *Keil*, and other modern Books of Aſtronomy. The moſt antient, and by far the moſt conſiderable Geometrical Method for determining the Parallax of the *Sun*, is that of the famous *Diagram* of *Hipparchus*, which was uſed by all the antient Aſtronomers. The ſecond Method is, by the Obſervation of the *Luna Dichotoma*, or *Moon*, when ſhe is in one of her Quarters, and appears to us exactly biſected. This Way was uſed by Aſtronomers of the laſt Age. The third Method is, by the Obſervation of the Parallax of *Mars*, invented by *Caſſini*, and followed by *De la Hire*, *Flamſteed*, and others. But after all their moſt diligent Obſervations, and the Uſe of the moſt exquiſite Inſtruments, they could arrive at no greater Preciſion than this, that the *Sun*'s Parallax was certainly more than nine Seconds, but leſs than twelve; ſo that the Diſtance of the *Sun* could not be known within a fourth or fifth Part of the Whole; whereas by the Doctor's new Method it will be known to an hundred Times that Exactneſs, and without any great Nicety or Skill required in the Inſtruments or Obſervers.

Venus's Semi-diameter, ſeen from the *Sun*, only ſubtends the fourth Part of a Minute, or fifteen Seconds: and that *Mercury*'s Semi-diameter, at his mean Diſtance from the *Sun*, is ſeen under an Angle ten Seconds only, and *Saturn*'s Semi-diameter under the ſame Angle; and that the Semi-diameter of *Jupiter*, the biggeſt of all the Planets, ſubtends no more than the third Part of a Minute at the *Sun*; whence, by Analogy, ſome modern Aſtronomers conclude, that the *Earth*'s Semi-diameter, ſeen from the *Sun*, ſubtends a mean Angle between the greater of *Jupiter* and the leſſer of *Saturn* and *Mercury*, and equal to that of *Venus*, viz. one of fifteen Seconds; and conſequently that the Diſtance of the *Sun* from the *Earth* is almoſt 14000 Semi-diameters of the latter *.

IV. Another Conſideration has made theſe Authors enlarge this Diſtance a little more; for ſince the *Moon*'s Diameter is ſomething more than a Quarter of the *Earth*'s Diameter, if the *Sun*'s Parallax be ſuppoſed fifteen Seconds, the Body of the *Moon* would be bigger than that of *Mercury*; to wit, a ſecondary Planet bigger than a primary one; which ſeems repugnant to the regular Proportion and Symmetry of the Mundane Syſtem.

V. But, on the contrary, it ſeems hardly conſiſtent with the ſame Proportion, that *Venus*, an inferior Planet, and without any Satellite, ſhould be bigger than our *Earth*, a ſuperior Planet, and accompanied with ſo remarkable a Satellite; therefore, at a Mean, ſuppoſing the *Earth*'s Semi-diameter ſeen from the *Sun*, or which

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* Sir ISAAC NEWTON collected from Mr. *Pound*'s Obſervations made with a Micrometer applied to the *Huygenian* Teleſcope of 123 Feet, that an Obſerver at the *Sun* would ſee *Saturn* at his mean Diſtance under an Angle of 16″; and *Jupiter* under an Angle of 37″. Mr. *Huygens* found the apparent Diameter of *Mars* not to exceed 11″. Dr. HALLEY himſelf obſerved the Diameter of *Mercury* to be 21″ $\frac{1}{2}$, and thence concludes that of *Venus* to be 30″ at her mean Diſtance (ſee *Philoſ. Tranſ.* N° 386.) in all theſe Caſes the Eye is ſuppoſed to be placed in the *Sun*.

Upon Suppoſition that the horizontal Parallax is 15 Seconds, the Diſtance of the *Sun* in Semi-diameters of the *Earth* is found by the following Analogy.

As the Tangent of	——	15″	——	5,861666
Is to Unity	——	1	——	0,
So is Radius	——	——	——	10,000000
To the Semi-diameters 13750 in the Diſtance of the *Sun*			——	4,138334

Accordingly if the Parallax be 12″ $\frac{1}{2}$, the Diſtance of the *Sun* will come out nearly 16500 Semi-diameters of the *Earth*.

is the ſame thing, the *Sun*'s horizontal Parallax, to be twelve Seconds and a half, the *Moon* will be leſs than *Mercury*, and the *Earth* bigger than *Venus*, and the *Sun*'s Diſtance from the *Earth* come out nearly 16500 Semi-diameters of the *Earth**.

VI. The Doctor admits of this Diſtance at preſent, till its preciſe Quantity be made to appear more certain by the Trial he propoſes; nor does he regard the Authority of ſuch as ſet the *Sun* at an immenſely greater Diſtance, relying on the Obſervations of a

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* A general Method for determining the Proportion of the Magnitude of the ſeveral Planets is eaſily deduced from the Ratio of their Diſtances from the *Sun*, which, according to the periodical Times of their Revolutions, are as follows:

☿	♀	⊕	♂	♃	♄
38710	72333	100000	152369	520096	954006

Therefore, let D = apparent Diameter of the *Sun*.
P = ditto of the *Earth*.
d = the apparent Diameter of the Planet.
a = Diſtance of the *Earth* from the *Sun*.
b = the proportional Diſtance of the Planet.
S = the real Diameter of the *Sun*.
E = ditto of the *Earth*.
N = ditto of a Planet.

Then it will be $D : P :: S : E$; and becauſe $d\times\frac{b}{a}$, is the apparent Diameter of the Planet ſeen from the *Sun* at the Diſtance of the *Earth*, therefore $D : d\times\frac{b}{a} :: S : N$. Conſequently $E : P :: N\, d\times\frac{b}{a}$; or $E : N :: a\,P : d\,b$; whence it appears, that the true Proportion of the Magnitudes of the Planet and *Earth* will be known when the *Sun*'s Parallax is determined; and that the Diameter of the Planet is reciprocally proportional to that Parallax, or half the Quantity P.

Upon Suppoſition therefore that the *Earth*'s apparent Diameter is 30″, and that of *Mercury* 20″, then the Proportion of their Magnitude will be as 100000 × 30 to 38710 × 20; that is, as 300000 to 77420, or as 109 to 28 nearly; whereas the Magnitude of the *Earth* is to that of the *Moon* as 109 to 30; therefore the Suppoſition makes *Mercury* leſs than the *Moon* in the Ratio of 28 to 30, or of 14 to 15. But if the *Sun*'s Parallax be 12″ ½, or the apparent Diameter of the *Earth* 25″, then 100000 × 25 is to 38710 × 20 as 109 is to 34 nearly; in this Caſe, therefore, the Planet ☿ will be bigger than the *Moon*, in the Proportion of 34 to 30. And the *Sun*'s Diſtance will be nearly 16500 Semi-diameters of the *Earth*. On the other hand, the *Sun*'s Parallax being 15″, that of *Venus* will be 54″ (ſee the Note to Art. VII.), and the Magnitude of the *Earth* and *Venus* will be as 100000 × 30 to 72333 × 54″, or as 30 to 39, nearly; ſo that *Venus* would, in this caſe, be near ¼ Part bigger than the *Earth*.

vibrating *Pendulum*, which are not, as it ſeems, accurate enough to determine ſuch minute Angles; at leaſt ſuch as uſe this Method will find the Parallax ſometimes none at all, and ſometimes even negative; that is, the Diſtance will become either infinite, or more than infinite, which is abſurd; and it is ſcarce poſſible for any one certainly to determine, by Means of Inſtruments, however nice, ſingle Seconds, or even ten Seconds; and therefore it is not at all ſurpriſing that the exceeding Minuteneſs of ſuch Angles has hitherto baffled the many and ingenious Attempts of Artiſts *.

VII. As the Doctor was making his Obſervations in the Iſland of St. *Helena*, about forty Years before, on the Stars round the South Pole, he happened to obſerve with the utmoſt Care *Mercury* paſſing under the *Sun*'s Diſk; and, contrary to his Expectation, he very accurately obtained, with a very good 24 Foot Teleſcope, the very Moment in which *Mercury*, entering the *Sun*'s Limb, ſeemed to touch it internally, as alſo that of his going off, forming an Angle of internal Contact; whence he diſcovered the preciſe Quantity of Time the whole Body of *Mercury* had then appeared within the *Sun*'s Diſk, and that without an Error of one ſingle Second of Time; for the Thread of Solar Light, intercepted between the obſcure Limb of the Planet, and bright Limb of the *Sun*, though exceeding ſlender, affected his Sight, and in the Twinkling of an Eye both the Indenture made on the *Sun*'s Limb by *Mercury* entering into it vaniſhed, and that made by his going off appeared. Upon obſerving this, he immediately concluded, that the *Sun*'s Parallax might be duly determined by ſuch Obſervations, if *Mercury*, being nearer the *Earth*, had a greater Parallax when ſeen from the *Sun*; for this Difference of Parallaxes is ſo very inconſiderable, as to be always leſs than the *Sun*'s Parallax, which is ſought; conſequently, though *Mercury* is to be frequently ſeen within the *Sun*'s Diſk, he will ſcarcely be fit for the preſent Purpoſe *.

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* The above Paragraph mentions the Vibrations of a Pendulum as the Means of determining the *Sun*'s Diſtance; but I find no mention made of this Method by any other Author; and from the Nature of the Thing, it muſt appear precarious, uncertain, and inſufficient for any ſuch Purpoſe.

VIII. Therefore, there remains *Venus*'s Tranſit over the *Sun*'s Diſk, whoſe Parallax, being almoſt four Times greater than that of the *Sun* †, will cauſe very ſenſible Differences between the Times in which *Venus* ſhall ſeem to paſs over the *Sun*'s Diſk in different Parts of our *Earth*: From theſe Differences, duly obſerved, the Dr. affirms, the *Sun*'s Parallax may be determined, even to a ſmall Part of a Second; and that without any other Inſtruments than Teleſcopes ‡ and good common Clocks, and without any other Qualifications in the Obſerver than Fidelity and Diligence, with a little Skill in Aſtronomy; for you need not be ſcrupulous in finding

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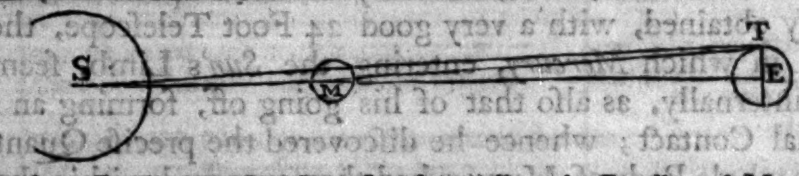

* The *Sun*'s Parallax having been ſtated at $12'' \frac{1}{2}$, the Parallax of *Mercury* is eaſily known by the known Ratio of its Diſtance from the *Sun* and *Earth*; but this will be beſt explained by a Diagram: Therefore let S be the *Sun*, M *Mercury*, and E the *Earth*, whoſe Semi-diameter is E T; draw the Lines S E, S T, and M T, then is the Angle T S E $= 12'' \frac{1}{2}$ the *Sun*'s Parallax, and E M T is the Parallax of *Mercury*, and the Difference of thoſe Parallaxes is the Angle M T S. Now as theſe Parallaxes, and their Difference, are proportional to the Lines M T, S T, and S M, which are in a given Ratio to each other; they will alſo have a conſtant Proportion among themſelves, and therefore when any one of them is known, or ſuppoſed to be known, the others will be known according to that Hypotheſis.

For Example; if the Solar Parallax T S E be $12'' \frac{1}{2}$, then it will be M T : S T (or M E : S E) : : 6129 : 10000 : : $12'' \frac{1}{2}$: $20'' \frac{3}{10} =$ T M E, the Parallax of *Mercury*, nearly; then the Difference is $7'' \frac{4}{5}$ for the Angle M T S, on the above Suppoſition. Now this Difference of Parallaxes is leſs than the *Sun*'s by more than $4'' \frac{1}{2}$; and ſince the Parallax of the *Sun* is to be found by the Difference of the Parallaxes from Obſervation, the Planet *Mercury* will not be ſo proper for this Purpoſe as *Venus*, where the Difference of Parallaxes will be ſo much more conſiderable.

† By the foregoing Proportions of the planetary Diſtances from the *Sun*, the Diſtance of *Venus* from the *Earth* is to the *Sun*'s Diſtance as 27668 to 100000; therefore ſay, as 27668 : 100000 : : $12'' \frac{1}{2}$: $45''$ nearly, which is the Parallax of *Venus*, from which take the *Sun*'s Parallax $12'' \frac{1}{2}$, there remains $32'' \frac{1}{2}$ for the Difference, or Parallax of *Venus* from the *Sun*, which is more than four Times as great as that of *Mercury*, $7'' \frac{4}{5}$, found in the laſt Note. Alſo *Venus*'s Parallax $45''$ is almoſt four Times larger than ($12'' \frac{1}{2}$) the Parallax of the *Sun*.

‡ If the *Sun* be viewed with a Teleſcope which magnifies about 15 or 20 Times, it will ſuffice for ſhewing the Contacts of the Limbs of the ſolar and venereal Diſks; and alſo if the Micrometer be adapted in the Focus of the Eye-glaſs, the Latitude of *Venus* in the Middle of the Tranſit may be meaſured, and thereby her Theory, Motion of her Nodes, &c. may with great Accuracy be aſcertained.

the Latitude of the Place, or in accurately determining the Hours with reſpect to the Meridian; it is ſufficient if the Times be reckoned by Clocks, truly corrected according to the Revolutions of the Heavens ‡, from the total Ingreſs of *Venus* below the *Sun*'s Diſk, to the Beginning of her Egreſs therefrom; when her opaque Globe begins to touch the bright Limb of the *Sun*; which Times, as the Dr. found by Experience, may be obſerved even to a ſingle Second of Time.

IX. But, by the limited Laws of Motion ‖, *Venus* is very

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‡ The Clocks or Watches uſed in obſerving this Phænomenon may be eaſily corrected, by obſerving the Revolution of a fixed Star to a given Object for a few Nights before-hand, in the following Manner.——Let a Teleſcope, with croſs Hairs in the Focus of the Eye-glaſs, be fixed in ſome convenient Place to obſerve the Tranſit of a Star over the vertical Hair; and there let it remain immoveable for ſome Time. Then obſerve the Moments of Time when the Star comes upon the vertical Hair two Nights ſucceſſively, and if the Time of this Revolution of the Watch or Clock, by which you obſerved it, be juſt 23 Hours, 56 Minutes, and 4 Seconds, you will be ſatisfied it goes true. But otherwiſe you muſt alter it, till you find it will ſhew the Return of the Star to the Hair ſooner by three Minutes and $56''$ each ſucceſſive Night, than the foregoing. For want of a Teleſcope, a ſmall Hole made in a Window-ſhut, to obſerve the Diſappearing of a Star behind a Chimney, or any opaque Object that is ſharp, will do nearly as well.—The Reaſon of ſuch Correction is, becauſe $3' : 56''$ of Time, anſwer to $59' : 8''$ of Motion, which is that by which the Motion of the *Earth* in 24 Hours exceeds one entire Revolution on its Axis, which is always made in $23^h : 56' : 4''$ preciſely.

The Reaſon why no great Accuracy in regard to the Latitude of the Place is neceſſary, will appear hereafter. Nor is it requiſite to define the Hour of the Day for the ſeveral Phænomena of the Tranſit; the Diſcovery of the ſolar Parallax depending only upon the true Quantities of the Duration thereof, and their Differences, as obſerved in two diſtant Places, on oppoſite Parts of the Meridian.

‖ In Tranſ. N°. 139 here referred to, the Dr. has ſhewn from the Theory of *Venus*'s Motions, the Method of aſcertaining the Times when ſhe will tranſit the *Sun*'s Diſk, both at the aſcending and deſcending Nodes, and tabulated them as below.

In the Month of NOVEMBER.

Year	Time of Conj.			Diſt. from Cent.		
	d.	h.	′	′	″	
918	20	21	53	6	12	B
1161	20	21	10	6	55½	A
1396	23	7	20	4	38	B
1631	26	17	29	16	11	B
1639	24	6	37	8	30	A
1874	26	16	46	3	3	B
2109	29	2	56	14	36	B
2117	26	16	3	10	5	A

In the Month of MAY.

Year	Time of Conj.			Diſt. from Cent.		
	d.	h.	′	′	″	
1048	24	13	45	3	50	B
1283	23	8	14	5	31	A
1291	25	15	9	14	27	B
1518	25	16	32	14	52	A
1526	23	9	37	5	6	B
1761	25	17	55	4	15	A
1769	23	11	00	15	43	B
1996	28	2	13	13	36	A
2004	25	19	18	6	22	B

N. B. In the Tables A denotes the Tranſit over the ſouthern Part of the ſolar Diſk, and B over the northern Part. And by adding 11 Days to the *Old Stile* of the Tables, they are adapted to the *New*.

rarely ſeen within the *Sun*'s Disk; and for a Series of 120 Years and upwards is not to be ſeen there once; that is, from 1639, when Mr. *Horrox* was favoured with this agreeable Sight, and he the firſt and only one ſince the Creation of the World, down to 1761 §; at which Time, according to the Theories hitherto found agreeable to the Heavens, *Venus* will paſs under the *Sun* on *May* 26 in the Morning *; ſo that (vide *Phil. Tranſ.* N°. 193.) at *London*, almoſt at ſix o'Clock in the Morning, ſhe is to be in the Middle of the *Sun*'s Diſk, and but four Minutes more ſoutherly than his Center; the Duration of this Tranſit will be almoſt 8 Hours; that is, from two till almoſt ten o'Clock in the Morning, and conſequently her Ingreſs will not be viſible in *England*; for the *Sun* at that Time being in 16° of *Gemini*, and almoſt in 23° of north Declination, ſhall be ſeen not to ſet throughout the whole northern frigid Zone; and conſequently the Inhabitants of the Coaſt of *Norway*, as far as its northern Promontory beyond the Town of *Drontheim*, may obſerve *Venus* entering the *Sun*'s Disk, and perhaps this Ingreſs into the Sun at his Riſing, may be ſeen by the Inhabitants of the North of *Scotland* and thoſe of *Zetland*; but when *Venus* is neareſt the *Sun*'s Center, the Sun will be vertical to the northern Coaſts of the Gulf of *Ganga*, or rather of the Kingdom of *Pegu*; and conſequently

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§ Mr. *Horrox* (whoſe Life is in Page 271 of our BIOGRAPHIA PHILOS.) from his Skill in Aſtronomy was able to predict the Tranſit of *Venus* in 1639; and having acquainted Mr. *Crabtree* therewith in a Letter dated *October* 26, 1639, he deſired him to obſerve it with all Attention poſſible, and particularly to meaſure the Diameter of *Venus*, which, ſays he, *Kepler* has made 7′, *Lanſbergius* 11′, but I can make it no more than 1′.

Accordingly when the Day came, he made his Room dark, and took in the *Sun*'s Diſk through a Teleſcope on a Paper Screen, and there obſerved the Tranſit, and found *Venus*'s Diameter to be nearly 1′ : 10″. After this (on *April* 20, 1640) he wrote to Mr. *Crabtree*, to inform him a ſecond Time, how much he had made the Diameter of the Planet in his Obſervation; for, ſays he, "That I have forgot, but I "remember what elſe you obſerved very well." Hence it appears that this Tranſit was obſerved by Mr. *Crabtree* as well as by himſelf, and that they mutually compared their Obſervations on the Subject. Of this Phænomenon Mr. *Horrox* gave a large Account in a Tract he publiſhed, entitled, *Venus in Sole viſa*, which 22 Years after was publiſhed by *Hevelius* with his *Mercurius in Sole viſus*.

* According to the Theories, on which the Tables publiſhed by *Caſſini*, *Flamſteed*, and *Street*, were conſtructed, the Calculation of the preceding Tranſit (in 1639) anſwered very well to Obſervation. For by Mr. *Horrox*, the geocentric Longitude of *Venus* was obſerved to be 7s : 14° : 26′ : 30″ at the Time of the total Ingreſs, and the Caroline Tables give but 1″ more. Again the obſerved geocentric Latitude at the ſame Moment was 10′ : 27″, and by the Tables it was 10′ : 30″. Since then, the Theory of *Venus* anſwered ſo nicely to Obſervation at that Time, one might expect it ſhould

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ſhould do ſo now; and therefore I ſhall give the Reader a Summary of the Calculation for the approaching Tranſit, which I have made from the ſame Tables.

The mean Motion of VENUS.	°	°	′	″
For *A. D.* 1761	2	16	34	55
May	6	12	15	20
Days 25	1	10	3	12
Hours 17	0	1	8	5
Minutes 55′	0	0	3	4
The mean Anomaly of *Venus*	10	10	5	12
The heliocentric Longitude of Ditto	7	15	42	20
Preceſſion of the Equinox add		29	46	16
Longitude from the Equinox	8	15	28	36
Place of the *Earth*	8	15	35	37
Difference	0	0	7	1
Place of the Node	8	15	2	0
Diſtance of *Venus* from ☋	0	0	26	36
Diſtance of *Earth* from ☋	0	0	33	57
Inclination of South	0	0	1	34

Curtate Diſtance of *Venus*	72668	
Diſtance of the *Earth*	101557	
As the *Sum*	174225	5,241099
To the Difference	28889	4.460732
So is the Tangent of ½ Sum of	89° : 56′ : 30″	12.996683
To Tangent of ½ the Difference	89 : 39 : 6	12.216316
The Parallax of the Orbit	179 : 35 : 36	
The Elongation of *Venus*	0 : 17 : 24.	
Then, as the Sine of *Commutation*	7′	0,845098
To the Sine of Elongation	17,4	1,240549
So is the Tangent of Inclination	1′ 34″	6,658703
		7,899252
To the Tangent of the Latitude of *Venus*, as ſeen from the *Earth*	3′ 54″	7,054154.

C Thus

ſequently in the neighbouring Countries, when the *Sun* ſhall, at the Ingreſs of *Venus*, be almoſt four Hours diſtant to the Eaſt, and almoſt as many to the Weſt at her Egreſs, her apparent Motion within the *Sun's* Diſk will be accelerated almoſt twice as much as is the horizontal Parallax of *Venus* from the *Sun*; becauſe *Venus* at that Time moves retrograde from Eaſt to Weſt; whilſt in the mean Time an Eye, on the Surface of the Earth, is carried the contrary Way from Weſt to Eaſt.

Thus it appears, that at the Middle of the Tranſit *Venus* will be diſtant from the *Sun's* Center 3′ : 54″; and becauſe the Dr. makes it but 4′, it is plain he computed by the ſame Theory or Tables. But by his own Tables lately publiſhed, this Latitude of *Venus* is made 9′ : 51″, as appears by Mr. *Metcalfe's* Computation in the following Table.

6 *June* 1761, Apparent Time A. M.	h.	m.	s.
Firſt Contact	2	5	23
Central Ingreſs	2	16	41
Total Immerſion	2	28	15
Middle of the Tranſit	5	24	17
Neareſt Approximation of Centers	5	24	50
Ecliptic Conjunction	5	46	17½
Emerſion	8	20	19½
Central Egreſs	8	31	54
End of the Tranſit	8	43	12
Central Duration	6	15	12
Duration of the Tranſit	6	37	49
Lat. of ♀ at the ecliptic Conjunction	9′	51″	16‴
Horary Motion of *Venus* from the *Sun*	3	56	57

A *French* Author in his *Ephemerides* has alſo made the Latitude and other Phænomena different from either of the foregoing. The Particulars whereof for the Meridian of *Paris*, are as follow.

	h.	′
The Ingreſs begins	13	47
——— is Central	13	58
——— Total	14	10
Middle of the Tranſit	17	14
Egreſs begins	20	9
——— Central	20	26
——— Total	20	42
Duration of the Tranſit	6	55
Latitude at the Conjunction	8′	57″

Beſides the Parallax, another great Uſe of the Tranſit will be to determine which of thoſe differing Theories, or Sets of Tables, are neareſt the Truth.

X. Suppoſing the *Sun*'s Parallax, as was ſaid, to be twelve Seconds and a Half, *Venus*'s Parallax will be forty-three Seconds; and ſubtracting the *Sun*'s Parallax, there will remain half a Minute at leaſt for the horizontal Parallax of *Venus* from the Sun, and conſequently *Venus*'s Motion will be accelerated ¾ of a Minute at leaſt from that Parallax, whilſt ſhe paſſes over the *Sun*'s Disk, in ſuch Elevations of the Pole as are near the *Tropic*; and ſtill more ſo in the Neighbourhood of the Equator; for *Venus* will at that Time accurately enough deſcribe within the *Sun*'s Diſk four Minutes an Hour, and conſequently at leaſt eleven Minutes of Time (by which the Duration of this Eclipſe of *Venus* will be contracted by Reaſon of the Parallax) anſwer to ¾ of a Minute; and by this Contraction alone we might ſafely determine the Parallax, provided the *Sun*'s Diameter and *Venus*'s Latitude were very accurately given, which yet we cannot poſſibly bring to a Calculation, in a Matter of ſuch great Subtilty *.

XI. There-

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* What relates to the *Geographical Phænomena* of the Tranſit, we have ſhewn in the INTRODUCTION, by the *terreſtial Globe*, which is infinitely preferable to any *Maps*, *Planiſpheres*, or *Projections* of any Kind for this Purpoſe; for they rather puzzle and perplex the ungeometrical Reader; but the Globe makes every Circumſtance natural and eaſy.

In the Figure to Article VII, T S is a Line drawn from the Spectator's Eye at T on the *Earth*'s Surface, to the Center of the *Sun*; and T M another Line drawn from the Eye to the Center of a Planet M; the Angle S T M which they contain, is called *the Parallax of the Planet from the Sun*, or the Difference of Places in which the Centers of the Sun and Planet appear from the Surface of the *Earth* at T, while at the ſame Time they appear from the Center E in the ſame Point or Line E M S.

This Angle S T M = T M E − T S M, or it is equal to the Difference between the horizontal Parallax of the Planet and Sun; which, in the Caſe of *Venus*, is 32″; but if we make the leaſt of it, and take the Doctor's Number 30″ for the Parallax of *Venus* from the *Sun*; then ſince *Venus*'s Motion upon the *Sun*'s Diſk is 4′ of a Degree *per* Hour (as appears from her Theory); therefore if we ſay, as 240″ of Motion : 60′ of Time : : 30″ of Motion : 45″ of Time, which is ¾ of a Minute, by which the Duration of her Tranſit is hourly contracted. But ſince the Tranſit is contracted at each End equally by the Parallax, the whole Contraction will be in Proportion to double that Parallax, or to 60″ of Motion, which is 1′ 30″ *per* Hour in Time. And ſince the whole Motion of *Venus* over the Diſk as ſeen from the *Earth*'s Center, is performed in about 7 Hours and 20′ (according to the Doctor's Hypotheſis) therefore $7\frac{1}{3} \times 1\frac{1}{2} = 11''$, the whole Contraction; ſo that to a Perſon at *Bengal*, the Duration of the Tranſit will be but 7 Hours and 9 Minutes.

Now ſince this Motion of *Venus* is eſtimated in Minutes of a Degree on the *Sun*'s Diſk, therefore if the *Sun*'s Diameter, and *Venus*'s Latitude, or Diſtance from the Center of the *Sun* at the Middle of the Tranſit could be accurately known, then from

a

XI. Therefore we muſt have another Obſervation, if poſſible, in Places where *Venus* poſſeſſes the Middle of the *Sun* at Midnight, under the oppoſite Meridian; that is, 6^h or 90° more weſterly than *London*, and where *Venus* enters the *Sun*'s Disk a little before his Setting, and goes off a little after his Riſing; which will happen in the ſaid Meridian in about 56° of N. Lat. that is, at *Nelſon*'s Harbour in *Hudſon*'s *Bay*; for in the neighbouring Places *Venus*'s Parallax will protract the Duration of the Tranſit, and make it at leaſt ſix Minutes longer; becauſe whilſt the *Sun* ſeems to tend under the Pole from Weſt to Eaſt, theſe Places on the *Earth*'s Surface will ſeem to be carried with a contrary Motion towards the Weſt; that is, with a Motion conſpiring with the proper Motion of *Venus*; conſequently *Venus* will ſeem to move ſlower within the *Sun*'s Disk, and continue longer thereon †.

XII. If

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a ſingle Obſervation made in Parts near the Equator, the Parallax of *Venus* from the *Sun*, and from thence the *Sun*'s Parallax itſelf, might ſafely be determined. But ſince the Latitude of *Venus* is at preſent uncertain from Theory, and can only be determined at the Time of the Tranſit, we have no Way left but to make as great a Difference as we poſſibly can between the Durations of the Tranſit, as obſerved at two different Places. As the Parallax of *Venus* from the *Sun* will be the Cauſe of that Difference, it is plain the more we can contrive to magnify the Effect, the more compleatly we ſhall be able to diſcover and eſtimate the Cauſe. And for this Purpoſe, another Part of the *Earth* muſt be choſen, in a very different Parallel, and on the oppoſite Meridian, as will be ſhewn in the next Note.

† That the Difference of the Durations of the Tranſit may be as great as poſſible, the two Obſervations are to be made in Places where the Beginning and End can both be obſerved, and where the Velocity of *Venus*'s Motion will be as different as ſuch a Condition will admit of; the Place therefore to which we are delegated for a ſecond Obſervation, is *Port Nelſon*, at the Mouth of *York* River in *Hudſon*'s Bay, in the Parallel of 56° Lat. The geographical Reaſons for all which, are explained by the terreſtrial Globe, in the Introduction.

As at *Bengal* the Tranſit is contracted, by Reaſon the Spectator's Eye is there carried in a Direction contrary to that of *Venus*'s Motion; ſo on the oppoſite Meridian, at *Port Nelſon*, the Motion of the Spectator will conſpire with that of *Venus*, and by that Means protract the Continuance of the Tranſit, as is evident from the Principles of Mechanics.

But the Quantity by which the Duration of the Tranſit is *contracted* in one Caſe, and *protracted* in the other, is proportioned to the Chord of the Arch through which the Spectator is carried by the *Earth*'s diurnal Motion from the Beginning to the End of the ſaid Tranſit; theſe Chords are, in the Parallel of the *Ganges*, 22° 30′, and of *Port Nelſon* 56°, as the Numbers 148 to 92 (as will appear hereafter) therefore ſay, as 148 : 92 : : 11′ : 6⅚. Wherefore at *Hudſon*'s Bay the Tranſit will be prolonged 6′ 50″, or its Continuance will be 7^h 26′ 50″.

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XII. If therefore, in both Places this Tranſit happen to be duly obſerved by proper Perſons, it is evident that the *Mora* will be

longer

That the young Aſtronomer (for whom this Comment is intended) may more readily ſee the Reaſon of the whole Affair, as far as Calculation is concerned in it, I ſhall lay before him a Specimen of a more accurate Computation for both Latitudes, which he will ſee illuſtrated by the Diagram in the Introduction, where A F E G is the *Earth*'s Equator; *G H*, the Orbit of *Venus*; *A B C*, the *Sun*; *Y D Z*, the Path of *Venus* of the ſolar Diſk. When therefore *Venus* juſt touches the *Sun*'s Limb internally, it will appear to an Eye at C, the *Earth*'s Center, in the Line *C Y*, and the Place in her Orbit is at S; but when ſhe touches the weſtern Limb internally at Z, then the Eye at C views her by the Ray C Z, and in the Orbit at V. So that S V is the Arch of angular Motion deſcribed in $7^h : 20'$ of Time, and is 110 Degrees, in the Equator = K L.

Let B I D H be the Parallax of 22° : 30′; and *a b* the Chord of the Arch *a* I *b*; thro' which the Eye is moved by the diurnal Rotation of the *Earth*, in $7^h : 9'$, from *b* to *a*, which is 107°. Draw through S the Ray *b* S *w*, alſo the Ray *b* Y; then will the Angle *w b* Y (the Parallax of *Venus* from the *Sun*), ſhew her at a Diſtance from the *Sun* to an Eye at *b* in *Bengal*, when ſhe is totally within the Diſk, viewed from the Center C. But when the Planet arrives at T, it is evident, the Ingreſs appears compleat to the Eye at *b*. Therefore it will happen ſo much ſooner at *b* than at C, as is equal to the Time ſpent in deſcribing the Arch S T.

Again, let *c f d* be the Parallel of 56°, and let the Eye of the Spectator at *Port Nelſon* be at *c*, to view the entire Ingreſs by the Ray *c* R Y; then it is evident the Planet at R will be there ſeen in the *Sun* ſooner than at the Center C, by the Time the Planet takes in deſcribing the Arch R S. Note, *c d* is the Chord of the Arch *c d* of the Parallel through which the Eye is carried in the Time of $7^h : 26' \frac{5}{7}$; and is equal to 111° : 45′ of diurnal Motion.

Therefore the Difference between the Moments of the entire Ingreſs as viewed at the *Ganges* (*b*) and at *Port Nelſon* under the oppoſite Meridian at (*c*) will be the Time in which *Venus* will paſs over the Arch R T. The whole Difference therefore of the two Durations will be double that Time, ſince the Parallax gives the ſame Difference of Time for the Egreſs as for the Ingreſs, which Difference therefore is $17' : 50''$.

Since the middle Moment of the Tranſit is nearly the ſame to an Eye at the *Earth*'s Center C, and to a Spectator at I, it is evident, the Difference which is made in the Time of the firſt half Duration at thoſe Points C and I, is occaſioned by the Motion of the Eye through the Arch *b I*, which is the very ſame as would happen if the Eye were carried in the right Line, or Chord *a b*, from *b* to *e*. And therefore that Difference will be as the Sine *b e* of half the Arch *b* I *a* = 107, or the Sine of 53° : 30′.

In like Manner it is ſhewn, that the Difference of the half Duration of the Tranſit at C and *c*, is proportioned to the right Line *c g*, or Sine of (half *c d*) 55° : 30′ at leaſt. Therefore the whole Difference of the Semi-durations at *Bengal* and *Port Nelſon*, will be as the Sum of thoſe Lines, or Sines, *viz.* as *b e* + *c g*.

If therefore in the *Earth*'s Semi-diameter C A continued out, we take C M = *b e* + *c g*, and draw the Line M Y, to cut the Orbit of *Venus* in Q, and join Q C; then it is plain, there will happen the ſame Difference in the Time of the Beginning of the Tranſit to an Eye placed at C, and another at M, as there will be to the two Spectators

at

longer by 17 entire Minutes in *Nelſon*'s Harbour than in the *Eaſt Indies*; nor does it matter much whether the Obſervation be made at *Fort St. George*, commonly called *Madras*, or at *Bencoolen* on the weſtern Coaſt of the Iſland of *Sumatra*, near the Equator; but if the *French* ſhould incline to make the Obſervation, *Pondecherry* on the weſtern Coaſt of the Gulf of *Ganga*, at the Elevation of 12° will be a proper Place for the Purpoſe; and for the *Dutch*, *Batavia* their famous Emporium, is a fit Place: And, indeed, the Dr. would have ſeveral Obſervations made of the ſame Phænomenon in different Parts, both for further Confirmation, and leſt a ſingle Obſerver ſhould happen to be diſappointed by the Intervention of Clouds from ſeeing what the Dr. does not know if thoſe either of the preſent or following Age ſhall ever ſee again; and upon which the certain and adequate Solution of the nobleſt, and otherwiſe moſt difficult Problem depends; therefore the Dr. again and again recommends it to the Curious ſtrenuouſly to apply themſelves to this Obſervation.

XIII. By this Means the *Sun*'s Parallax may be diſcovered to within its five hundredth Part, which doubtleſs will ſeem ſurpriſing to

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at (*b*) and (*c*). Alſo that there will be the ſame parallatic Angle S C Q in each Caſe, or the Arch $QS = (ST + SR =)\ RT$.

Then becauſe the *Sun*'s Diameter $AE = 31'$, the Angle Y C Z will be $= 29' : 30''$ nearly; and therefore as the Arch S V, which meaſures that Angle in the Orbit of *Venus* is paſſed over in $7^h\ 20' = 440'\ 5$ and an Arch $= 2\ QS$ in $17' : 50''$; if we ſay as $26400'' : 1076'' :: 29'\ 30'' = 1770'' : 72''$; the half of which is $36'' = SCQ$, the Parallax of *Venus* from the Sun for the Baſe or Diſtance C M.

If the *Earth*'s Semi-diameter $AC = 10000$, then the Sine of $53° : 30' = be = 7426$; and the Sine of $55° : 30' = cg = 4629$; whence their Sum is $CM = 12055$. We have alſo ſhewn (Note to Article IX) that the Diſtance of the *Earth* from the *Sun* $CY = 10155{,}7$ and the Diſtance of *Venus* $QY = 7266{,}8$; from whence the Diſtance of the *Earth* from *Venus* will be found $2923{,}4 = CQ$. Therefore ſay, as $QY = 726 : 36'' = SCQ :: QC = 292 : 14''\ 30''' = CYQ$ or CYM, which is the Parallax of the *Sun* for the Diſtance C M. And therefore alſo the Parallax of *Venus* $MQC = 50'' : 36'''$.

But laſtly, to adapt theſe horizontal Parallaxes of the *Sun* and *Venus* to the *Earth*; we muſt ſay, as $CM = 12 : AC = 10 :: 50''\ 36''' : 46''\ 34''' = AQC$, the horizontal Parallax of *Venus*. And $12 : 10 :: 14''\ 30''' : 12''\ 5''' = AYC$, the horizontal Parallax of the *Sun*, on the Suppoſition that the different Duration of the Tranſit in the Latitudes of 22° 30′ and 56° be obſerved to be 17′ 50″.

And if the Obſervation be made at *Fort St. George*, *Bencoolen*, *Pondecherry*, *Batavia*, or other Places near the *Equator*, it is evident the Chord *a b* will be greater, and the Difference of the Durations will ſtill be longer, and therefore give the *Sun*'s *horizontal Parallax* in Proportion more accurately.

ſome; yet notwithſtanding, if an accurate Obſervation be had in both Places abovementioned, it has already been ſhewn, that the Duration of theſe Eclipſes of *Venus* differ from each other by 17 entire Minutes, upon the Suppoſition that the *Sun*'s Parallax is 12 Seconds and a Half; and if this Difference be found to be greater or leſs by Obſervation, the *Sun*'s Parallax will be greater or leſs almoſt in the ſame Ratio; and ſince 17 Minutes of Time anſwer to 12 Seconds and a Half of the *Sun*'s Parallax, for each Second of the Parallax there will ariſe a Difference of upwards of 80 Seconds of Time; therefore if this Difference be had true within two Seconds of Time, the Quantity of the *Sun*'s Parallax will be had to within the fortieth Part of one Second; and conſequently his Diſtance will be determined to within its five hundredth Part at leaſt, if the Parallax be not found leſs than what the Dr. ſuppoſes it; for, 40 × 12 and $\frac{1}{2}$ is 500 *.

XIV. Here the Dr. has had no Regard to the Planet's Latitude, both to avoid the Trouble of a more intricate Calculation, which would render the Concluſion leſs evident, as alſo on Account of the Motion of the Nodes of *Venus* not being hitherto diſcovered, and which cannot be duly determined but by ſuch Conjunctions of the Planet with the *Sun* as this; for it was only on the Suppoſition that the Plane of *Venus*'s Orbit is immoveable in the Sphere of the fixed Stars, and that her Nodes would continue in the ſame Places wherein they were in 1639, that it was concluded that *Venus* would paſs four Minutes below the *Sun*'s Center: And if in 1761 ſhe ſhould paſs more ſouther~~ly,~~ it will be evident that there is a Regreſſion of the Nodes; but if more northerly, that there is a Progreſſion of them; and that at the Rate of five Minutes and ⅘ in 100 *Julian* Years, for each Minute, by which the Path of *Venus* will at that Time be more or leſs diſtant from the *Sun*'s Center than the ſaid four Minutes; but the Difference between the Durations of theſe Eclipſes will be ſomewhat leſs than 17 Minutes, by Reaſon of the ſouthern Latitude of *Venus*; but greater, if, by the Progreſſion of the Nodes, ſhe ſhall paſs over the *Sun* to the North of his Center †.

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* It appears by the laſt Note, that if the Difference of the Duration of the Tranſit at the *Eaſt Indies* and *Hudſon's Bay* be $17' : 50'' = 1070''$, then the *Sun*'s horizontal Parallax will be 12'' at leaſt; therefore $1070'' : 12'' :: 1'' : \frac{12}{1070} = \frac{1}{1070}$ of 12''; or each Second of the Difference in Duration will correſpond to the 1070th Part of the *whole Solar Parallax*. Therefore the Diſtance of the *Sun*, which is proportional to the Parallax, will, in this Caſe, be diſcovered to be within at leaſt a 1000th Part of the Whole.

But if the Nodes of *Venus*'s Orbit have a retrograde Motion, and ſo occaſion her to paſs over the Diſk with a much more ſouthern Latitude, according to the Doctor's own Tables, the *Mora* will be leſs, as alſo the Difference of the Tranſit's Duration at the above Places; but though it ſhould be found to be but one half the Quantity we have now ſuppoſed it, yet even then it will give the *Sun*'s Parallax and Diſtance to within a 500th Part of the Whole; which is more than 100 Times the Accuracy our beſt Obſervers could ever yet pretend to; for they have only diſcovered that the *Sun*'s Parallax is more than 9'', but leſs than 12'', and ſo leave us in doubt about a fourth Part of the Whole; which, according to our preſent Reckoning, is not leſs than (20000000, or *twenty Millions of Miles*. And indeed if we make the beſt uſe poſſible of this moſt favourable Opportunity, we muſt after all ſit down with the diſagreeable Aſſurance, that we can never arrive to the Knowledge of the *Sun*'s true Diſtance within 80 or 100 *thouſand Miles*.

XV. But

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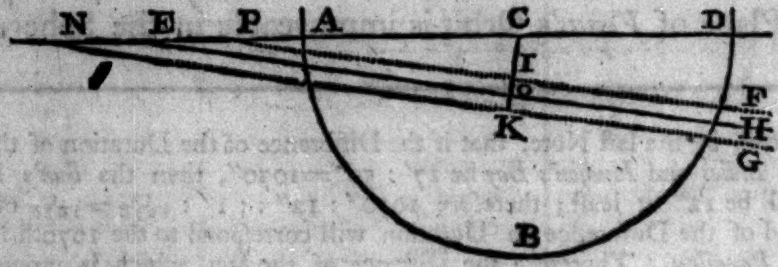
† What the Latitude or Diſtance of *Venus* will be from the Center of the *Sun* at the true Conjunction cannot be known, till it be determined at what Rate the Nodes of *Venus*'s Orbit do move; which may be eaſily diſcovered at the Time of the Tranſit, but hardly by any other Means. But in order to elucidate what the Doctor ſays farther in this Paſſage, we add the following Diagram:



Let A B D be the ſouthern Half the *Sun*'s Diſk, C his Center, N D a Portion of the Ecliptic, E the Place of the Node in 1639, E H the Path of *Venus* at that Time, and C G her neareſt Diſtance from the *Sun*'s Center; then it is plain, if the Node E be at Reſt, or continues ſtill in the ſame Place, then alſo E H will now be her Path, the ſame as before; for the Angle C E O, which her viſible Path makes with the Ecliptic, will always be the ſame, whether the Nodes move or not, as we ſhall ſhew hereafter.

It will alſo be ſhewn, that the Angle C E O is 8° : 28′, and ſince C O = 4′; therefore in the right-angled Triangle C E O we have this Analogy, as Sine C E O = 8° 28′ : C O = 4 : : Radius : C E = 27′ = the Node from the *Sun*'s Center. Then if we take O K = O I = 1′, we ſhall have C K = 5′, and C I = 3′; and then it will be C O : C K : : (4 : 5 : :) C E : C N : : 27 : 33,8; whence C N — C E = E N = 6,8 = the Space through which the Node muſt apparently go forward, to cauſe *Venus* to paſs one Minute *more ſoutherly* in the Path N K G, or leſs ſo in the Path P I F, for N E = E P, as all her Paths are parallel.

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XV. But for the Sake of ſuch as are not thoroughly acquainted with the Doctrine of Parallaxes, the Doctor further explains the Matter, both by a Figure, and a ſomewhat more accurate Calculation: Therefore, ſuppoſing that at *London*, *May* 25. 17ʰ 55′ 1761, the *Sun* be in 15° 37′ of *Gemini*, and conſequently, that at his Center, the Ecliptic tends towards the North in an Angle of 6° 10′; and that the viſible Path of *Venus* within the *Sun*'s Disk does at that Time deſcend towards the South, forming an Angle with the Ecliptic of 8° 28′; the Path of *Venus* will tend a little towards the South in reſpect of the Equator, interſecting the Parallels of Declination in an Angle of 2° 18′: Suppoſing likewiſe, that *Venus* be near the *Sun*'s Center at the ſaid Time, and diſtant therefrom to

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The Doctor in his Tables places the aſcending Node in ♊ : 13° : 37′ : 44″, at the Beginning of the Year 1661; and in the Year 1761 the Place of the ſame Node is ♊ : 14° : 29′ : 24″; the Motion therefore of the Node in 100 *Julian* Years will be 51′ 40″. From the Year 1639 to 1761 are 122 Years; therefore, as 100 : 51′ 40″ : : 122 : 63′ = Space thro' which the Node moves forwards in 122 Years; but the Equinox in the ſame Time recedes 99′, therefore the apparent Motion of the Nodes will be retrograde at the Rate of 36′ in 122 Years: ſince therefore *Venus*'s Diſtance from the Node in our Calculation is 26′ : 36° (ſee Note * to Art. IX.) to which a geocentric Latitude of 4′ correſponds; if we add the above Motion of 36′ to 26′ ½, the Sum is 62′ ½, by which the Node will be diſtant from the Planet; and therefore ſince 26′ 36″ : 4′ : : 62 : 9 ½ nearly; therefore if the Doctor's Tables are right, we expect the neareſt Approach of *Venus* to the *Sun*'s Center to be about 9 ½ Minutes.

Here we cannot but obſerve how little was known, or ſaid, of the Motion of *Venus*'s Nodes about 40 years ago: It is certain the Doctor knew of no ſuch Motion when he wrote this Eſſay; and I never could find the leaſt Mention of any ſuch Thing in any Pieces he afterwards publiſhed. Sir *Iſaac Newton* poſitively denies ſuch a Motion, and his learned Commentators the *Jeſuits*, and other Aſtronomers ſince, as Mr. *De la Caile*, &c. Indeed a ſmall Motion of the *Aphelia* and Nodes will accidently ariſe from the perturbating Forces of the larger Planets; but this is too ſmall to be regarded in the Theory of *Mercury* itſelf.

Nay, Dr. *Halley* has himſelf attempted to prove there is no ſenſible Motion of the Nodes of the Planets; for he found that of *Mercury* to amount to no more than 39′ : 50″ in 46 Years; and 38′ : 20″ of this was owing to the Receſſion of the Equinox, and therefore the proper Motion of the Nodes was only 1′ : 30″ in ſo long a Time. *Therefore*, ſays the Doctor, *we may ſafely aſſume the Plane of the Orb of Mercury to be immoveable in the Sphere of the fixed Stars.*

And indeed the Motion of the Nodes of *Mercury* which is found in his Tables, is only 1° : 23′ : 20″ in 100 Years, which is the very ſame with that of the *Equinox* itſelf. The ſame Motion of the Node is alſo allowed to *Jupiter*; as alſo to the Node of *Mars*, though miſprinted 1° : 3′ : 20″. But for what Reaſon we have the Motion of *Venus*'s Node 51′ : 40″, and the Motion of *Saturn*'s Node 30′, the Editors of thoſe Tables have not thought fit to acquaint us. I fear there is too much Reaſon for their Exclamation — *Utinam Auctor, dum viveret, illas edidiſſet.* See further concerning the Motion of the Nodes, in a particular Diſcourſe hereafter.

wards the South four Minutes, deſcribing by a retrograde Motion on the *Sun*'s Diſk four Minutes an Hour; the *Sun*'s Semi-diameter will nearly be 15′ 51″, and that of *Venus* 37″ and ½; and ſuppoſing, for Trial Sake, the Difference of the horizontal Parallaxes of *Venus* and the *Sun* to be 31″, ſuch as it is on the Suppoſition of the *Sun*'s Parallax being 12″ and ½ *.

XVI. Therefore let a ſmall Circle, as A B D Fig. 3. be deſcribed from the Center C, whoſe Semi-diameter let be 31″, repreſenting the *Earth*'s Diſk, and therein drawing D *a b* E and *c d e* the Ellipſes of the Parallels of 22 and 56 Degrees N. Lat. in the ſame Manner as is now uſed by Aſtronomers for conſtructing Solar Eclipſes; let B C A be the Meridian wherein the *Sun* is, to which let be inclined the Right Line F H, repreſenting the Path of *Venus* in an

Angle

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* We are now come to the moſt material and eſſential Part of the Doctor's Eſſay, wherein the Tranſit is more directly explained by *Calculation*, *Projection*, and *Inſtrumental Menſuration*; but with ſo much Brevity, as to require ſome Degree of Illuſtration for duly underſtanding every Part.

The *Sun*'s Place being given in *Gemini* 15° : 37′, there is given in a right-angled ſpherical Triangle, the Hypothenuſe = 75° : 37′, and the Angle at the Baſe = 23° 30′ = Obliquity of the Ecliptic, to find the Angle at the Perpendicular, which will come out 83° 50′, the Complement of which is 6° : 10′, which Angle the Ecliptic makes with the Parallel of the *Sun*'s Declination; and therefore is the *Direction of the Ecliptic Northwards* in that Point which the *Sun* then poſſeſſes.

It is farther ſaid, *that the viſible Path of* Venus *makes an Angle with the Ecliptic of* 8° 28′. To illuſtrate this; let N C be the Ecliptic, N the Node, and N B the proper Orbit of *Venus*, whoſe Inclination is the Angle C N B = 3° : 24′. Then ſuppoſe the *Earth* and *Venus* were viewed from the *Sun*, and were at any Moment to ſet out together from the Node N, then in one Hour the *Earth* would appear to paſs over the Space of 2′ : 28″ = 148″ = N E; and in the ſame Time *Venus* will paſs over 4′ = 240″ = N V. Through the Point V draw the Line E A, and that will be a Direction or apparent Path of *Venus* to an Eye on the *Earth* in the Ecliptic at E. But in the Triangle N E V, there are given the two Sides N E and N V, and the included Angle at N, to find the Angle at V, which therefore is known (by Inſtit. 719). Then the Angle V E C = N + V (by 632) = 8° 28′. And becauſe the mean Motions of the *Earth* and *Venus* are conſtant, the Spaces deſcribed by them in the ſame Time, will be always in the ſame conſtant Ratio, and therefore the Angle A E C will be invariable.

Since therefore the Ecliptic tends Northwards of the Equator 6° : 10′, and the Orbit of *Venus* tends Southwards of the Ecliptic 8° : 28′; therefore *Venus* will tend *Southwards in Regard to the Equator* in the ſmall Angle of 2° : 18′. As to the *Motions*, *Semi-diameters*, and *horizontal Parallaxes* of the *Sun*, *Venus*, and the *Earth*, they are taken from the Tables for any given Time.

Note, If the Diſk of the *Earth*, and the Poſition of *Venus*'s Orbit were projected on a Plane, as ſeen from the *Sun*, then the Axis of the Ecliptic and that of *Venus*'s Orbit would both lie on the ſame Side of the Axis of the Meridian B C A; in this Caſe, there is no retrograde Motion of the Planet; but ſince this retrograde Motion

is

Angle of 2 18′, whoſe Diſtance from the Center C let be 240 Parts, whereof B C is 31, and from C let fall the Right Line C H perpendicular upon F G; and ſuppoſing the Planet in H at 17^{h} 55′ or 5^{h} 55′ in the Morning, let the Right Line F G H be divided into the Horary Spaces III. IV, IV. V, V. VI, *&c.* equal to C H, that is, four Minutes; let the Right Line K L be alſo equal to the Difference of the apparent Semi-diameters of the *Sun* and *Venus*, or 15′ 13″ and ¼; and the Circle deſcribed with the Radius K L, and from any Point within the ſmall Circle, repreſenting the *Earth*'s Diſk as a Center, will meet the Right Line F G in the Point denoting what o'Clock it is at *London*, when *Venus* ſhall touch the *Sun*'s Limb in an Angle of internal Contact in that Place of the *Earth*'s Superficies that lies under the aſſumed Point on the Diſk; and if a Circle deſcribed from the Center C, and with the Radius K L, meet F G in the Points F and G, the Right Lines F H, H G will be = 14′ 41″, which *Venus* will appear to paſs over in 3^{h} 40′; therefore F will fall upon 2^{h} 15′ at *London*, and G upon 9^{h} 35′ in the Morning; whence it is evident, that if the *Earth*'s Magnitude ſhould, by Reaſon of the immenſe Diſtance, vaniſh as it were into a Point; or if, diveſted of its diurnal Motion, it ſhould always have the *Sun* vertical to the ſame Point C, the entire *Mora* of this Eclipſe would continue for ſeven Hours and ¾; but in the mean Time, whilſt the *Earth* revolves with a contrary Motion to that of *Venus* through 110 Degrees of Long. and conſequently the Duration of the ſaid *Mora* is ſhorter, ſuppoſe 12 Minutes, it will nearly be 7^{h} 8′, or 107 Degrees*.

XVII.

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is the Thing to be ſhewn, it is very eaſy to ſee that the Orbit of *Venus* muſt have a contrary Situation, and conſequently that the Axis muſt be on the contrary Side of the Meridian, and therefore the *Difference*, and *not the Sum*, of the two Angles is to be taken for the Angle e C H, as the Doctor has preſcribed.

* The PROJECTION the Doctor here ſpeaks of, for conſtructing *Solar Eclipſes*, is the *Orthographic* One (whoſe Principles are explained in the INSTITUTIONS of the GENERAL MAGAZINE, as being a Part of the SCIENCE of PERSPECTIVE). The Eye in this Projection is ſuppoſed to be placed in the *Sun*'s Center, viewing the Motions of the Planets in their Orbits on a *Perſpective Plane*; and therefore the Diameters of the Planets muſt be drawn in ſuch Proportion as they appear on that Plane.

Let S be the *Sun*'s Center (Fig. 2.) C that of the *Earth*, and M the Center of *Venus*, and ſuppoſe the Perſpective Plane to paſs through the Point M perpendicular to the viſual Ray S M. Let A E D F be the *Earth*, and A C its Semi-diameter, ſubtending to the Eye at S, the Angle A S C = 12″ ½ = *Sun's horizontal Parallax*. But it is evident the apparent Magnitude of A C on the perſpective Plane at M will be H M. Parallel to H A (or S A) draw M B, then will the Angle B M C = A S C, and A B = H M.

Laſtly,

XVII. Now in the Meridian itſelf *Venus* will be near the *Sun*'s Center at the Eaſtern Mouth of the *Ganges*, where the Elevation of the Pole is about 22°; therefore that Place will be equally diſtant from

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Laſtly, draw A M; then is A M C = *Venus's horizonal Parallax*; from which if you take the Sun's = B M C, there will remain the *horizontal Parallax of* Venus *from the Sun* = A M B = H A M. Now in ſuch ſmall Angles we have A C : A B : : A M C : A M B; and conſequently the *Earth*'s Semi-diameter A C is diminiſhed on the perſpective Plane in H M in the Ratio of *Venus*'s horizontal Parallax A M C = $43'' \frac{1}{2}$ to her Parallax from the *Sun* = $43'' \frac{1}{2} - 12'' \frac{1}{2} = 31''$, which therefore muſt be the Semi-diameter of the ſmall Circle repreſenting the *Earth*'s Diſk on the Plane at the Orbit of *Venus*.

But to an Eye at the *Sun*, *Venus*'s Semi-diameter G M ſubtends an Angle G S M = $15''$; and ſince H S M = $12'' \frac{1}{2}$; therefore ſay, as $12'' \frac{1}{2} : 31'' : : 15'' : 36'' \frac{1}{2}$ = G M the Semi-diameter of *Venus* as meaſured in Seconds of a Degree on the ſame Plane; but the Doctor makes it $1'$ more, *viz.* $37'' \frac{1}{2}$.

Therefore, if from the *Sun*'s Semi-diameter $15' : 51''$ we take that of *Venus* $37'' \frac{1}{2}$ there will remain $15' : 13'' \frac{1}{2}$ for the Difference. Then from a *Scale of equal Parts* take 951 = ($15' : 51''$ =) C L, and on the Point C, as a Center, deſcribe a Circle repreſenting the *Sun*'s Diſk on the perſpective Plane, Part of which is here denoted by S L U (Fig. 3.) then take in the Compaſſes 31 = A C, and deſcribe on the ſame Point C the ſmall Circle A E B D for the Diſk of the *Earth*. Again, take $913 \frac{1}{2}$ (= $15' : 13'' \frac{1}{2}$) = C I, and deſcribe the Arch V I Y, whoſe Diſtance from the *Sun*'s Limb will be I L = $37 \frac{1}{2}$ the Semi-diameter of *Venus*.

Let C L be the Ecliptic on the *Sun*'s Diſk; then becauſe it makes an Angle with the Meridian (paſſing through the *Sun* in the middle Moment of the Tranſit) of 83° : 50′; therefore make the Angle L C H = 83° : 50′, and H C B, or rather A B, will be that Meridian on the Diſk of the Earth.

Again, ſince the viſible Path of *Venus* makes an Angle with the Ecliptic of 8° : 28′ whoſe Complement is 81° : 32′, therefore make the Angle L C e = 81° : 32′ and C e will be perpendicular to the Path of *Venus*, on the *Sun*'s Diſk. But ſince her Latitude is $4' = 240''$, therefore from the Scale take 240, and ſet from C to e; and through the Point e draw a Line G e at Right Angles to C e, and that will be the *viſible Path of* Venus *on the Solar Diſk*.

The Angle e C H = 2° : 18′ being ſo ſmall, the Doctor has neglected it in his Diagram, and ſuppoſed H C perpendicular to the Path of *Venus*; and ſince (by Calculation) the Middle of the Tranſit is at $5^h : 55'$ in the Morning; and alſo, at that Time, the horary Motion of *Venus* is juſt $4'$ = H C; therefore, if you take the Line C H, and apply it Parallel-wiſe from 60 to 60 in the Line of Lines on the Sector; and then take the Diſtance between 55 and 55 on the ſame Lines, and ſet one Foot of the Compaſſes in H, the other will fall on the Point V, in the Line G H, in which Point the Planet will be at 5 o'Clock for the Time at *London*. Having this Point given, take in the Compaſſes the Line C H, and Place one Foot in V, the other will mark IV on one Side, and VI on the other; and in this Manner the other Hours III and II are found; and thus the Line G H is divided into Hours, and then each Hour may be ſub-divided into Minutes, as you ſee in the Figure.

The Line G H will cut the Curve V Y in F, whereon, if a Circle be deſcribed with the Radius = I L = $37'' \frac{1}{2}$, it will repreſent the Diſk of *Venus* juſt entered the *Sun*, and from the *Sun* on both Hands in the Moments of the Planet's Ingreſs and Egreſs, *viz.* 53° and ½, as the Points *a b* in the greater Parallel D *a b* E; but the Diameter A B will be to the Diſtance *a b*, as the Square of the Radius to the Rectangle under the Sines of 53° and ½ and 68°; that is, as $1'\,02''$ is to $46''\,13'''$; and upon making a due Calculation, the Doctor finds, that the Circle deſcribed with the Radius K L from the Center *a*, will meet the Right Line F H in the Point M, at $2^{h}\,20'\,40''$; but deſcribed from the Center *b*, it will meet H G in N at $\mathrm{IX}^{h}\,29'\,22''$ at *London*; conſequently the whole Body of *Venus* will be ſeen from the Banks of the *Ganges* within the *Sun*'s Diſk for $7^{h}\,8'\,42''$; therefore we have rightly ſuppoſed its Duration $7^{h}\,8'$, ſince here a Part of a Minute is inconſiderable*. XVIII.

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and in internal Contact with its Limb, ſuch as it appears in that Caſe from the Center of the *Earth* at C; for the Line C F = C I. And becauſe in the Right-angled Triangle C F H, there is given the Side C H $= 240''$, and C F $= 913''$ ½; we ſhall have $FH = \sqrt{CF^2 - CH^2} = 880''$; then ſay, as $240'' : 1^{h} :: 880'' : 3^{h}\,40'$; which deducted from $5^{h} : 55'$, will leave $2^{h} : 15'$ for the Time of the Morning when *Venus* will be juſt within the ſolar Diſk; but added thereto, it makes $9^{h} : 35'$, the Time when the Egreſs begins, and conſequently the whole Duration of the Tranſit to an Eye at the Center C, or at Reſt on the Middle of the Earth's enlightened Diſk, would be juſt 7 Hours and 20 Minutes, in which Time 110 Degrees of Longitude will paſs the Meridian.

* But, as we have ſhewn, the Surface of the Earth being in Motion, and in ſome Parts that Motion conſpires with, and in others it is contrary to that of *Venus*; it follows, that in the latter Caſe there will be ſome Places, as (*a*) and (*b*) where the Tranſit will be of a leſs Duration, and others as (*c*) and (*d*) where it will be longer than at the Center C.

Suppoſe by the contrary Motion from (*a*) to (*b*) in the Parallel of $22^{\circ} : 30'$, the *Mora* be contracted 12 Minutes, or that it laſteth but $7^{h} : 10'$, then will the Arch *a b* = 107 Degrees, and conſequently *a* C $= 53^{\circ} : 30'$ in that Parallel. Now in order to determine the Time of the Beginning at the Point (*a*) we muſt illuſtrate the Principles of Calculation and Projection by a larger Figure of the Earth's Diſk.

Therefore from a *larger Scale of equal Parts*, take in your Compaſſes 31, and on the Point C deſcribe the Semicircle F B G (Fig. 4.) and project the Elliptic Meridian and Parallel for the given Point (*a*), whoſe Poſition on the Diſk is then determined by Calculation in the following Manner. Since the Arch D G $= 22^{\circ} : 30'$, its Complement D B $= 67^{\circ} : 30'$. Then we have Radius : Sine of D G :: C G : D O :: 31 : 11,8 = D O = C H. Again, R : *s* D B :: 31 : 28,74 = H D. Then becauſe C G : H D :: R : *s* D B; and H D : M *a* :: R : *s* C *a* $= 53^{\circ} : 30'$; therefore by Compoſition of Ratios, we have C G : M *a* :: R^2 : *s* B D × *s* C *a*; whence M *a* = 23,1.

The Arch *a* D $= 36^{\circ} : 30'$, therefore R : *s* D *a* :: H C : K *a* = H M :: 11,8 : 7,1. Whence C H — H M = 4,7 = M C = *a* N. Having therefore M *a*, and *a* N, the Point (*a*) is given in Poſition on the Diſk.

Therefore (in Fig. 3.) from (*a*) let fall the Perpendicular *a g*, then will it be 240 + 4,7 = 244,7 = *a g*. Alſo H *g* = M *a* = 23,1; then ſay, as 240 : 60′ :: 23,1 :

5′:

XVIII. But adapting the Calculation to *Nelſon*'s Harbour, the Doctor finds that *Venus* ſhall paſs under the *Sun*'s Diſk when he is juſt about to ſet, and emerge out of his Diſk immediately after his riſing; that Place, in the mean Time, being carried through the Hemiſphere oppoſite to the *Sun* from c to d, with a Motion conſpiring with that of *Venus*; therefore the *Mora* of *Venus* within the *Sun*'s Diſk will become longer by reaſon of the Parallax, ſuppoſe by four Minutes, ſo as intirely to be $7^{h}\ 24'$ or 111° of the Equator; and ſince the Latitude of the Place is 56 Degrees, it will be as the Square of the Radius to the Rectangle under the Sines of 55° and ½ and 34°, ſo is $AB = 1'\ 2''$ to $cd = 28''\ 33'''$, and upon duly makeing the Calculation, it will appear, that the Circle deſcribed from the Center c, with the Radius K L, will meet the Right Line F H in O at $2^{h}\ 12'\ 45''$; but deſcribed from the Center d, it will meet H G in P at $IX^{h}\ 36'\ 37''$; wherefore the Duration of the *Mora* at *Nelſon*'s Harbour will be $7^{h}\ 23'\ 52''$; to wit, greater than at the Mouth of the *Ganges* by $15'\ 10''$ of Time*.

XIX.

$5' : 48''$, which added to $5^{h} : 55'$ gives $6^{h} : 0' : 48''$ for the Time when the Planet will be at g.

The Point (a) being determined on the Diſk; take the Diſtance C I in your Compaſſes, and ſetting one Foot in (a) deſcribe the Arch W Z, which will cut the Path of *Venus* in M, and thereby ſhew the Time of the entire Ingreſs as ſeen from the Place under (a) to be at $2^{h} : 20' : 48''$. This alſo appears from Trigonometrical Calculation; for the Triangle aMg is nearly the ſame as C F H; and therefore, $gM = HF$; whence $Hg = FM = 5' : 48''$, which added to the Time at $F = 2^{h} : 15'$ gives $2^{h} : 20' : 48''$, the Time at M. Hence twice $5' : 48''$, or $11' : 36''$ will be the Time by which the Tranſit will be ſhortened at the Parallel of 22° : 30′.

* Again (in Fig. 4.) let (c) be in the Parallel of 56°, and the Motion of the Earth there conſpiring with that of *Venus*, the Tranſit will be thereby prolonged, which ſuppoſe to be 4 Minutes. Therefore to the whole Duration $7^{h}\ 24'$ there will anſwer 111° of the Equator, or in the Arch of the Parallel between (c) and (d), the Half of which is 55° : 30′, alſo the Co-Latitude is 34°. Then proceeding as above, we have $R : s\ 34° :: CF : ge :: 31 : 17{,}3 = ge$. And as $R : s\ 56° :: CF : Cg :: 31 : 25{,}7 = Cg$. Alſo, $R : s\ 55°\ 30' :: eg : cm :: 17{,}3 : 14{,}3 = cm$. And becauſe of the Circles E C D and epf being parallel, we have $HD : ge :: HC : gp = 7{,}1$. And then, laſtly, we have $R : s\ 34°\ 30' = ce :: gp : cn = gm :: 7{,}1 : 4 = gm$; whence $Cg + gm = 29{,}7 = Cm$.

If therefore from the Point (c) (Fig. 3.) we let fall the Perpendicular (cf) then $fH = (cm) = 14{,}3$, and then $240 : 60' :: 14{,}3 : 3'\ 33''$, which taken from $5^{h}\ 55'$, leaves $5^{h}\ 51'\ 27''$, the Time of the Morning when *Venus* will be at (f). Then taking the Line C I in the Compaſſes, and ſetting one Foot in (c) deſcribe the Circle T X, this will cut *Venus*'s Path in O at $2^{h}\ 13'\ 27''$; the Time when *Venus* will appear at (c) juſt within the ſolar Diſk,

Or

XIX. But if *Venus* ſhould paſs without Latitude, the ſaid Difference will become 18′ 40″; but if ſhe ſhall be four Minutes more northerly than the *Sun*'s Center, the Difference will be increaſed to 21′ 40″, and will be ſtill greater by increaſing the Planets N. Lat.

From the above Hypotheſis it follows, that at *London Venus* ſhall riſe entering into the *Sun*, and at $9^h\ 37'$ in the Moruing, in her Egreſs, touch internally the *Sun*'s Limb, and quite leave his Diſk not before $9^h\ 56'$ †.

XX. It is evident from the ſame Hypotheſis, that *Venus* ſhould touch with her Center the extreme Northern Limb of the *Sun* on *May* 23, 11^h 1769; ſo that, by Reaſon of the Parallax, her whole Body may be ſeen, in the Northern Parts of *Norway*, within the *Sun*'s Diſk; whilſt on the Coaſt of *Peru* and *Chili*, ſhe ſhall ſeem to ride on the Diſk of the ſetting *Sun*, with a ſmall Segment of

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Or thus by Calculation; in the Right angled Triangle $c\,O\,f$ there is given the Perpendicular $cf = CH + Cm$ (Fig. 4.) $= 269{,}7$, and the Hypothenuſe $cO = 913{,}5$; therefore the Baſe $Of = \sqrt{Oc^2 - cf^2} = 872{,}5$. Then ſay, as $240 : 60' :: 872{,}5 : 2180' = 3^h\ 38'$; which taken from $5^h\ 51'\ 27''$ leaves $2^h\ 13'\ 27''$, the Time at (c) as before.

Wherefore the Time of the intire Ingreſs at (c) *Port Nelſon* will precede the ſame at (a) *Bengal* by about 7′ 21″; and therefore the whole Duration will be near 15′ longer in the former Place than in the latter.

† But if the Node ſhould be in the *Sun*'s Center C (or the Tranſit be central), and the Path of *Venus* be N C; then it is evident that $fg = PR$ (Fig. 3.) $= Ma + cm$ (Fig. 4.) $= 23{,}1 + 14{,}3 = 37{,}4$; becauſe in this Caſe, the Diſtance of (a) from the Line N C nearly vaniſhes, and that of (c) is inconſiderable. Therefore ſay, as $240 : 60' :: 37{,}4 : 9'{,}35 = 9'\ 21''$; the Difference of Time in the Beginning of the Tranſit at *Bengal*, and *Nelſon*'s *Harbour*, the Double of which, *viz.* 18′ 42″ will be nearly the Difference of the whole Durations in this Caſe.

If *Venus* ſhould paſs with 4 Minutes of North Latitude, then, by adapting the Trigonometrical *Calculus*, as before for 4′ South Latitude, the Difference of the *Mora* in thoſe Places will be found 21′ 40″. And, indeed, as ſhe goes more Northerly, the Difference will encreaſe as you may plainly ſee in the Diagram, the Diſtance P R is greater than O M, and T W is greater than P R, becauſe the Arch T X does ſenſibly recede from the Arch V Y as it goes Northwards; making the Difference O F, P Q, T V to encreaſe to a certain Limit, while the other Parts F M, Q R, V W, vary but little on all this Part of the Diſk.

Since on that Day at *London* the *Sun* riſes but a few Minutes before IV, therefore ſhe will be advanced upon the *Sun*'s Diſk at his Riſing to the Place in her Path where you ſee her repreſented in the Scheme. So that near *two Hours* of the Tranſit will be loſt to us.

As the Diameter of *Venus* is 75″, if we ſay as $240 : 60' :: 75 : 18', 75 = 18'\ 45''$, that will be the Time which paſſes between the external and internal Contact with the *Sun*, or ſo long as ſhe will be tranſiting the *Sun*'s Limb.

her Body; as in like manner in the *Molucoa* Iſlands, and neighbouring Parts, at Sun-riſing: But if the Nodes of *Venus* be found to have a Retroceſſion (as there is Reaſon to ſuſpect from ſome later Obſervations) then her whole Body being every-where ſeen within the *Sun*'s Diſk, the greateſt Difference of theſe Eclipſes will afford a ſtill more evident Proof of the *Sun*'s Parallax ‡.

XXI. How, from Obſervations made in the *Eaſt Indies* on the Ingreſs and Egreſs of *Venus*, compared with thoſe which are made in *England* on her Exit from the Solar Diſk, the ſame Parallax may be derived; to wit, *by adapting the Angles of a Triangle given*

in

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* This Paragraph relates to the Tranſit of *Venus* in the Year 1769, on *June* 3d, at eleven o'Clock at Night, and therefore inviſible to us. Upon the Hypotheſis *that the Nodes are at reſt*, the Center of *Venus* will nearly touch the Northern Part of the *Sun*'s Limb, becauſe the Latitude of *Venus* will in that Caſe be 15′ : 43″, and the *Sun*'s Semi-diameter is then about 15′ 50″. (See the Table in Note ‖, Art. IX.)

But, by an apparent retrograde Motion of the Nodes, the Planet will paſs with leſs Latitude; and if that Motion be ſuch as reſults from ſome modern Obſervations, the Tranſit will be very conſiderable, and of much greater Uſe in determining the Parallax of the *Sun* than that of next *June*.

CASSINI, in his Elements of Aſtronomy, has collected the following Obſervations of the Motions of the Venereal Nodes.

From an Obſervation of *Timocharis*, 271 Years before Chriſt, of *Venus* eclipſing the Star *n* in the Southern Wing of *Virgo*, it is computed that the Node of *Venus* was at that time in ♉ : 24° : 2′.

By the Obſervation of *Horrox*, in 1639, the Place of the Node was found to be in ♊ 13° : 28′ 22″.

By an Obſervation made in 1698, it was found by Calculation, that the Place of the Node was found in ♊ 14° : 1′ : 45″.

By another Obſervation in the Year 1705, the Place of the Node was found in ♊ 14° : 2′ : 52″.

In the Year 1710, the Node was found in ♊ : 14° : 04′ : 52″.

And in the Year 1731, the Place of the Node was in ♊ : 14° : 17′ : 02″.

From theſe Obſervations you will eaſily find that the Motion of the Node is at a Mean, 34″ *per Annum*. But Dr. *Halley*'s Tables make it 31″ yearly.

Alſo it is evident, that 1731 + 271 = 2002, or from the Time of *Timocharis*, to the Year 1731, there are 2002 Years, in which Time the retrograde Motion of the Equinox, or Node of the *Earth*, is 27° : 48′ : 20″; it is plain, if the Nodes of *Venus* were fixed, they would have appeared to have moved ſo much forwarder in the Ecliptic; but they have appeared to go forwards only 20° : 15′ : 2″; therefore the Difference 7° : 33′ : 18″ is the true retrograde Motion of the aſcending Node in that Time.

Laſtly, it muſt be obſerved, that ſince the Orbit of *Venus* lies within that of the *Earth*, the *real retrograde* Motion of the *aſcending Node* will produce an *apparent direct* Motion of the *deſcending Node*, which is the Reaſon why the Motion of this Node is

contrary

in Specie in the Circumferences of three equal Circles, I ſhall take another Opportunity to ſhew ‡.

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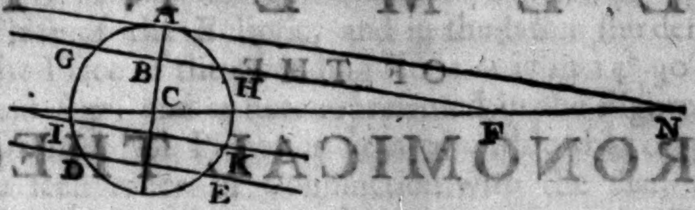
contrary to that of *Venus* in all the Diagrams we have hitherto made uſe of, as alſo in that which follows, for a further Illuſtration of this moſt important Affair.



Let A D E be the *Sun*, C N the Ecliptic, A N the Path of *Venus*, and N the Node. Now if the Node be at Reſt, the neareſt Diſtance of the Planet from the Center, will be A C = 15′ 45″. And ſince the Angle A N C = 8° 28′, we ſhall find C N = 106 the Diſtance of the Node from the Center C.

But if the Nodes have a retrograde Motion, and equal to that in the Doctor's Tables, then ſince from the laſt Tranſit in 1639, to that in 1769, are 130 Years, this Node will appear to have gone forward in that Time 38′ 30″ nearly; therefore 106 — 38,5 = 67′,5 = F C, and F will be the Place of the Node in this Hypotheſis.

Then drawing F G parallel to A N, it will be the Path of the Planet; and B C its Diſtance from the *Sun*'s Center, which is known from this Analogy, as 106 : 15,75 : : 67,5 : 10 = B C. Therefore the Path of *Venus* G H, upon the ſolar Diſk in this Tranſit, will be very little leſs than D E in the next Tranſit 1761, according to the Doctor's Tables.

But the Tranſit G H will be greatly preferable to the Tranſit D E for determining the *Sun*'s horizontal Parallax, becauſe, as we have ſhewn, a Tranſit on the North Part of the ſolar Diſk, will give the Difference of Duration in the *Mora* greater than one in the ſouthern Part, every Thing elſe being equal; and the Tranſit G H happens to be nearly in that Part of the Diſk where that Difference of Time will be a *Maximum*, and conſequently will afford the beſt Opportunity that can be for Succeſs in this Diſcovery.

‡ Whether the Doctor did ever give the Solution of this Problem we know not, nor have we met with it in any other Author. We ſhall therefore leave it to our learned Correſpondents (in our MAGAZINE) to oblige the Public with it.

THE ELEMENTS OF THE ASTRONOMICAL THEORY OF THE PLANET VENUS, WITH REGARD TO CALCULATIONS from TABLES.

IT is impoſſible for any one to underſtand the Nature of the Tranſit of *Venus*, and the Computations and Calculations relative thereto, without being previouſly acquainted with the Aſtronomical Principles of this Planet's Motions, which, therefore, I ſhall here briefly explain. Let ♈ ♋ ♎ ♑ repreſent the ECLIPTIC or Path of the *Earth* about the *Sun* S (ſee Figure 1. Plate III.), in which let the *Earth* be at T, and ſuppoſe the Diſtance T S divided into 100,000 equal Parts; then by the known Laws of Motion, the Squares of the periodical Times in any two Planets are always proportioned to the Cubes of their mean Diſtances; and ſince the Times in which the *Earth* and *Venus* revolve about the *Sun* are known, and the *Earth*'s Diſtance T S is equal to 100,000, therefore the Diſtance of *Venus* will be found, by the above Analogy, 72,333 of the ſame Parts, and conſequently if from a Scale of equal Parts we take that Number, and on the Center S deſcribe the dotted Circle B ☊ C ☋. Then that would be a proper Repreſentation of the Orbit of *Venus*, if that Planet moved in the Plane of the Ecliptic, and in a circular Orbit.

But as her Orbit is inclined to the Plane of the Ecliptic in an Angle of 3° 24′ nearly, one Part thereof will lie above the Plane of the Ecliptic, as ☊ E G ☋; and the other below, as ☊ H ☋; and the common Interſection, or Line ☋ S ☊, is called the Line of Nodes, and the Point ☊ is called the *aſcending Node*, and the other Point ☋ the *deſcending*, becauſe at the former ſhe aſcends above the Plane of the Ecliptic, and in the latter ſhe deſcends below it. The Place of the aſcending Node ☊ is in 14° 30′ of *Gemini* in the preſent Age, and as here repreſented in the Figure.

As the Orbit of the Planet is ſituated within that of the *Earth*, ſhe will be ſeen twice in Conjunction with the *Sun*, viz. in the Points R, Q, which are in a right Line drawn from the *Earth* to the *Sun*; that at R is called the *ſuperior Conjunction*, and that at Q the *inferior*.

Suppoſing her Orbit circular, as Q C R B, and in the ſame Plane of the Ecliptic; then if two right Lines were drawn from the *Earth* at T, to touch the Orbit of *Venus* in the Points I, K, they would determine the Angle of greateſt Diſtance that this Planet could ever appear from the *Sun*. Thus as ſhe deſcends from her ſuperior Conjunction R, ſhe will appear to go further from the *Sun* continually, till ſhe arrives to the Point I, and there ſhe will appear at the greateſt Diſtance from the *Sun* at S; afterwards, as ſhe advances towards her inferior Conjunction Q, the Diſtance from the *Sun* gradually decreaſes. From Q her apparent Diſtance from the *Sun* again increaſes till ſhe arrives at K, and from thence decreaſes as ſhe advances by C towards R.

This Angle I T S of her greateſt apparent Diſtance, is called the Angle of her *greateſt Elongation* from the *Sun*: And becauſe the Triangle S I T is right-angled at I, and the two Sides S T and S I are known, from thence we find the Angle S T I of about 48° which therefore is the greateſt Diſtance ſhe can ever be elongated from the *Sun*.

It is farther evident, that to a Spectator at the *Earth*, the Planet *Venus*, all the while ſhe is moving through the Part of her Orbit K C R B I, will appear to be *direct* in Motion, or to move according to the Order of the Signs from Weſt to Eaſt. But at the Point I the Direction of her Motion is changed; and during her Paſſage from I, by Q to K, her Motion will be contrary to the Order of the Signs, or from Eaſt to Weſt; and therefore ſhe is, during this Time, ſaid to be *retrograde*.

Hence alſo it appears, that ſince the large Part of her Orbit K R I, and the ſmaller Part I Q K, are both ſeen or deſcribed under the ſame Angle I T K, therefore her Motion in the former Caſe muſt be very ſlow in Compariſon of the latter; and as at the Points I K, her Direction is for a little Time before and after, ſenſibly in the right Lines I T, T K, and conſequently ſhe muſt be ſeen in the ſame Part of the Heavens during thoſe times, therefore ſhe is then ſaid to be *ſtationary*.

Were the Earth at reſt in T, the Space of Time between two Conjunctions of the ſame Kind, would be equal to the periodical Time of the Planet, which is nearly 225 Days; but ſince both the *Earth* and *Venus* move together the ſame Way, this Time between the two Conjunctions will be very much enlarged beyond the periodical Time of either: For if the Conjunction be at Q, then the Planet muſt perform one Revolution, and ſo much of another as is equal to the Motion of the *Earth* between the Times of the two Conjunctions. Let the *Earth*'s Motion in that Time be called A, then it will be * as $8766^h : 5392^h :: 360^\circ + A : A$; and by Diviſion of Proportion $8766 - 5392\ (= 3374) : 5392 :: 360 : A$. And therefore $A = \frac{5392 \times 360}{3375} = 575$ Degrees nearly; which angular Motion the *Earth* makes in one Year, ſeven Months, three Weeks and one Day, which is the Time ſought between the two Conjunctions.

The Particulars we have now mentioned are upon the Suppoſition that the Orbit of *Venus* is in the Plane of the Ecliptic; but it makes very little Difference if we conſider her Orbit as inclined thereto in the ſmall Angle above-mentioned.

We have likewiſe hitherto ſpoken of her Orbit as Circular, but it is in reality Elliptical; in one of whoſe Focus's the *Sun* is placed. The longer Axis of her Ellipſis cutting the Ecliptic in about the 7th Degree of *Leo* and *Aquarius*, as in the Figure is ſhewn by the Line M V, and upon her Plane A S is her greateſt, and E S her leaſt Diſtance from the *Sun*; and therefore the Point A is called the *Aphelion*, and E the *Perihelion*; and the greateſt Diſtance S A is to the leaſt Diſtance S E, as 72857 is to 71823.

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* The Period of the *Earth* is $365^\circ : 6^h = 8766^h$, and the Period of *Venus* $224^\circ : 16^h = 5392^h$.

N. B. The Theorem from whence the above Analogy is derived, you may ſee in Inſtit. 244 of the *General Magazine*.

Let P be the Place of a Planet in its Orbit, and let fall the Perpendicular P L to the Plane of the Ecliptic; then is L, the Place of the Planet, *reduced to the Ecliptic*. Draw S P and S L, and they will contain an Angle P S L, which is called the *heliocentric Latitude* of the Planet, becauſe the real Latitude P L of the Planet from the Ecliptic, is thereby meaſured as ſeen *from the* Sun. Draw the Line T P and T L, and they will contain an Angle P T L, under which the Latitude of the Planet P L is ſeen *from the* Earth, and therefore this Angle is called the *geocentric Latitude*, and theſe two Angles are inverſely as their Diſtances from the Planet; that is, the heliocentric Latitude P S L is to the geocentric Latitude P T L, as the Diſtance of the *Earth* T P is to the Diſtance of the *Sun* S P from the Planet.

The Diſtance of the Planet P from the Node, or the Arch P☊, is called the *Argument of Latitude*. Suppoſe T D the greateſt Latitude; that will meaſure the Inclination of the Planet's Orbit to the Ecliptic, as it will differ not ſenſibly from the Arch of which it is the Sine; therefore we ſhall have the following Analogy; as Radius to the Sine of the Planet's Diſtance from the Node, ſo is the Inclination of the Orbit to the Latitude P L of the Planet at P; which Latitude ſeen from the *Earth*, will always be of a different Quantity, according to the different Diſtances of the *Earth* from the Planet.

The Diſtances of the Planet from the *Sun* and the *Earth* in the Ecliptic, *viz.* S L and T L, are called the *curtate Diſtances*; and in the Triangle T S L, in the Plane of the Ecliptic, the Angle T S L is called the *heliocentric Longitude* of the Planet from the *Earth*; as being the Difference between the Place of the *Earth*, and that of the Planet (reduced to the Ecliptic), ſeen from the *Sun*. The Angle L T S is the *geocentric Longitude* (but more commonly called the *Elongation* of the *Planet* from the *Sun)*, which is the Difference between the Place of the *Sun* and of the Planet in the Ecliptic, as ſeen from the *Earth*. Laſtly, The Angle S L T is called the *Parallax of the annual Orbit*, as being ſubtended by the Semi-diameter S P of the *Earth*'s Orbit. Note, The Angle T S L is commonly called the *Angle of Commutation*.

Not only the Orbit of the Planet *Venus*, but thoſe of all the other Planets, are Elliptical, and particularly that of the *Earth*; and therefore the Diſtances of the *Earth* from the *Sun* will always be unequal; the greateſt Diſtance will be 10169, and the leaſt 9831, the mean Diſtance being 10,000, as we mentioned before.

The Longitude, or Place of the *Earth* or Planet, is its Diſtance in the Ecliptic from the Beginning or firſt Point of *Aries*; and what is called the mean Anomaly, is the Diſtance from the Aphelion Point, as from the Point A in the Orbit of *Venus*; and is eſtimated in Signs and Degrees of the Ecliptic.

From what has been ſaid, it will be eaſy to underſtand the Proceſs of Calculation by Aſtronomical Tables; in which we find the Longitude, the mean Anomaly, the Place of the Aphelion and Node, the Equation of the Orbit, the curtate Diſtances, the Argument of Latitude and Reduction to the Ecliptic, all ready calculated for the *Earth* or *Sun*, and all the other Planets; ſo that by this Means we are enabled, at any Time, to find the geocentric Place, Latitude, and Diſtance of the Planets, as Occaſion ſhall require; an Example of which Method of Calculation you will ſee in Page 9. of Dr. *Halley*'s *Diſſertation*, and it is the ſame with regard to any other Tables, as well as the *Caroline* there made uſe of.

OF THE
NODES of VENUS,
AND THEIR
MOTION and PLACE in the ECLIPTIC.

AS the *Place* and *Motion* of the Nodes of *Venus*'s Orbit are the two Hinges on which the whole Doctrine of the Tranſit turns, they cannot be too well aſcertained and underſtood; and therefore we may a little wonder, conſidering what a Number of Obſervatories have been erected in the different Parts of *Europe* for a Century paſt, that our Obſervations on the Place and Latitude of *Venus* are ſo very few, and made by ſo ſmall a Number of Perſons. I, for my own Part, have ſeen little on this Head, beſides what is contained in *Caſſini*'s Aſtronomy, either in regard to the Place or Motion of the Nodes of *Venus*.

It is evident from the foregoing Theory (Plate III. Figure 1), That if an Obſervation be made of a Planet's Place and Latitude, as ſeen from the *Sun*, and this be done on each Side of the Node ☊, before and after its Paſſage through it, that then the Place of the Node ☊ may be eaſily determined by Calculation; and theſe Obſervations being repeated at diſtant Times, will give the Motion of the Node and its Direction. It may be proper to illuſtrate this by an Example, which I ſhall give from the before-mentioned Author.

On the 2d of *September*, at 15 Minutes after Two (N. S.) the true Place of *Venus* was obſerved in ♎ 16° 30′ 50″ with North Latitude 5′ 41″. Afterwards, on the 6th Day of the ſame Month, her Place was obſerved at 18′ after Two to be in ♎ 21° 18′ 20″, with South Latitude 7′ 13″; then having computed for theſe Obſervations the true Places of *Venus* ſeen from the *Sun*, it will be found that her Place for the Firſt was in ♐ 11° 19′ 2″, and the Second ♐

17° 40′ 23″, and then the Place of the Node is found by the following Analogy; as the Sum of the Two Latitudes 12′ 54″ is to the Latitude of the firſt Obſervation 5′ 41″, ſo is the Motion of *Venus* between the two Obſervations (which was 6° 21′ 21″) to 2° 48′; which being added to the Place of *Venus* in the firſt Obſervation, gives the Place of the Node in ♐ 14° 7′, which is the deſcending Node, becauſe her Latitude at the firſt Obſervation was North, and at the ſecond South.

Again, on the 7th of *September*, at 19 Minutes paſt Two, her geocentric Place was found to be in ♎ 22° 27′ 30″ with 11′ 31″, and by Computation her heliocentric Place for the ſame Time was in ♐ 19° 15′ 30″; now comparing this with the firſt Obſervation on the 2d of the ſame Month, we have the following Analogy; as the Sum of the two Latitudes 17′ 12″ is to the firſt Latitude 5′ 41″, ſo is 7° 56′ 28″ (the Motion of *Venus* in the Interval) to 2° 37′ 30″. Theſe being added to *Venus*'s true Place in the firſt Obſervation, give the Place of her Node in ♐ 13° 56′ 30″, which is 10′ 30″ more than was found by the preceding Analogy; and therefore taking the Mean, we ſhall have the Place of the deſcending Node, on the 4th of *September* 1698, in ♐ 14° 1′ 45″.

Afterwards other Obſervations were made in the Year 1731, on the 7th and on the 14th Day of *April*, and from thoſe Obſervations the Place of the ſame Node was determined, in the Manner above ſpecified, to be in ♐ 14° 17′ 2″, more advanced by 15′ 17″ than on 4th of *September* 1698, which is at the rate of 28″ *per Annum* for the Motion of *Venus*'s Nodes.

By other Obſervations made by the Moderns, by *Horrox* at the laſt Tranſit, and by *Timocharis* 271 Years before the *Chriſtian Æra*, our Author has made ſuch Calculations as determine the annual Motion of *Venus*'s Node to be at a Mean 34″, *per Annum*.

When ſuch Obſervations and Calculations were ſo eaſy, and already furniſhed to their Hands, one may very well wonder that ſome of our greateſt Aſtronomers ſhould be altogether ſilent about the Motion of the venereal Nodes. Indeed, in the Aſtronomical Tables of PTOLEMY and KING ALPHONSUS, there is no Mention made of the Nodes of *Venus*, or their Motion: But in Tables that were publiſhed more than 100 Years ago, *viz.* by *Jeremiah Shakerley*, in 1653, intituled, *Tabulæ Britannicæ*, we find the Place of *Venus*'s Node is conſidered and allowed for, at the Rate of 50′ 16″ in 100 Years, which is at the Rate of 30″ *per Annum*.

The RUDOLPHINE *Tables*, compiled from the Obſervations of *Tycho*, *Kepler*, and others, do alſo allow for the Motion of *Venus*'s Node 78′ 10″ *per Century*, which is at the Rate of 47″ *per Annum*. Theſe were compiled and publiſhed by *John Baptiſta Morinus*, Regius Profeſſor of Mathematics at *Paris*, in the Year 1651; concerning which the Author aſſures us, that the Places of the Planets, as found by his Tables, differ not a Minute from their Places found by the Tables and Methods deduced from *Kepler*'s Obſervations.

In the Year 1661, thoſe called the CAROLINE *Tables* were publiſhed by Mr. *Thomas Street*; but in them we find no Mention of *Venus*'s Nodes, or their Motion, although he relates many Obſervations that were made of this Planet by *Tycho*, *Mæſthlinus*, *Kepler*, *Gaſſendus*, and others.

In the Year 1702, Mr. *De la* HIRE, Regius Profeſſor of the Mathematics at *Paris*, publiſhed his *Aſtronomical Tables* at the Command of *Lewis the Great*, in which he allows a Place to the Node of *Venus*, and a Motion of 1° 16′ 48″ *per Century*, which is 46″ *per Annum*; but a very little differing from the Rudolphine Tables.

Soon after this another Collection of Tables was publiſhed by Mr. *Whiſton*, ſaid to be thoſe of Mr. *Flamſtead*, Dr. *Halley*, Mr. *Caſſini*, and Mr. *Street*; in this Collection there is no Mention made of the Nodes of *Venus*, or any Motion conſidered; nor is there for any other of the Planets. What thoſe Tables were which he calls Mr. *Flamſtead*'s or Mr. *Caſſini*'s, I know not: But as for thoſe publiſhed under Dr. *Halley*'s Name, and by *Caſſini* the younger, they allow for the Nodes of *Venus*, and for the Nodes of the reſt of the Planets.

In Dr. HALLEY'*s* Tables, which were printed in the Year 1719, the Motion of *Venus*'s Node is ſtated at 51′ 40″ in 100 Years, which is at the Rate of 31″ *per Annum*.

Laſtly, The Table publiſhed by *Caſſini the Son*, in the Year 1740, contains, perhaps, the trueſt Account of the Motions of the Planet's Nodes in general, and that of *Venus* in particular; it makes that to be 57′ 40″ in 100 Years, which is at the Rate of 34″ *per Annum*, and therefore, if the Tranſit of *Venus* be calculated by thoſe Tables of Mr. *Caſſini*, the Phaſes and Times thereof will be different ſrom thoſe which are calculated by Dr. *Halley*'s Tables, and probaby nearer the Truth.

THE
DOCTRINE of PARALLAXES
MORE FULLY
EXPLAINED.

AS we purpoſe to ſhew and explain the Method of determining the various Phænomena of the Tranſit by means of Parallaxes, as the moſt natural and truly aſtronomical of any, it will be previouſly neceſſary to give the Reader as diſtinct an Idea of this important Point as we poſſibly can.

We have already ſhewn, that by the Word Parallax nothing more is meant than the Difference of Place in which any Object is ſeen from two different Points of View. Thus if the Planet V (Fig. 2.) be viewed from the Center of the *Earth* at T, its apparent Place will be at C, in a Plane F G placed indefinitely beyond it in the Heavens. But if the ſame Planet be viewed from the Surface of the Earth at E, its apparent Place will be at D; and this Difference, C D, of apparent Places, is called the PARALLAX of that Object in the Heavens.

Let K L M repreſent the *Sun*, and let the Viſual Rays T C, E D, in their Way to the Plane F G, croſs a Diameter of the *Sun* in the Points H I; then will the Diſtance H I be the Difference of the apparent Places of the Planet on the Face of the *Sun*. If the Spectator's Eye be placed at the Point (*e*), the Planet will appear on the Plane F G at the Point (*c*), and the Difference of the apparent Places of the Planet ſeen from the Center of the *Earth* T, and by a Spectator at (*e*) will only be C c. Laſtly, a Spectator at the *Earth*'s Surface at O, which is in the right Line T V, joining the *Earth* and Planet, muſt neceſſarily obſerve the Planet in the ſame Point C, as if he had viewed it from the Center of the *Earth*; and in this Caſe, as there can be no Difference of apparent Place, there can be no Parallax at all.

From what we have ſaid it is evident, that the Difference of the apparent Places C D (or C c), or the Quantity of the abſolute Parallax is proportional to the Angles T V E and T V e, which Angles are therefore called the *Parallatic Angles*, or Angles which meaſure the *Parallax*. Theſe Angles are proportioned to the Sines of the Arch O e and O E, or to the Diſtances of the Spectator from the Point O, to which the Planet is vertical. It is evident, when the Arch O E is 90°, or when the Planet appears in the Horizon, that then the Angle E V T, or the Parallax, is greateſt of all; and is in that Caſe called the *Horizontal Parallax*, being that under which the Semi-diameter of the *Earth* is ſeen from the Planet, and of which we have more particularly treated in the Note to the VIIth Paragraph of Dr. HALLEY's Diſſertation, Page 6.

The Parallax hitherto conſidered is properly called the *Abſolute Parallax*, and has reſpect to one Point V, ſeen from two different Places. But there is another Sort or Diſtinction of a Parallax, which may be properly called the *Relative Parallax*, which has Reſpect to the different Places in which two Objects appear from one given Point T. Thus the Center V of a Planet, and the Center S of the *Sun*, ſeen from the Center of the *Earth* T, appear at C and A, and when viewed from the Point E, they appear at D and B. But ſince the Diſtance of the Planet T V, and that of the *Sun* T S, are very unequal, the Parallax A B of the *Sun*, and that of the Planet C D, will be unequal in Proportion, or the Center of the *Sun* S will have a much leſs Depreſſion from A to B than that which the Center of the Planet has from C D, therefore theſe two Centers of the *Sun* and Planet are relatively depreſſed, as viewed from the Point E thro' a Space which is equal to A D — A B; therefore make D b equal to A B, then will A b be the Quantity of Depreſſion, or *relative Parallax*, by which the Center of the Planet V is removed from the Center of *Sun* S upon the Plane F G, and this is called the *Parallax of the Planet from the Sun*; and when we ſpeak of the apparent Diſtance of the Planet from the *Sun*'s Center on the Face of the *Sun*, we conſider the Diſtance S I to be diminiſhed in the Ratio of A D to A b on the Plane, or we take the Difference between the abſolute Parallax of the Planet H I, and that of the *Sun*, whenever we make any Computation of the Diſtance of a Planet from the Ecliptic by means of the Parallax, as we ſhall hereafter more fully explain and illuſtrate, by an Application of this Doctrine to the Tranſit obſerved by *Horrox*, in the Year 1639, having firſt premiſed the general Theory of Calculation by Parallaxes, which next follows.

THE

THE

COMPUTATION by PARALLAXES

EXPLAINED; and APPLIED to the

TRANSIT of VENUS,

For Aſcertaining the TIMES of its Duration in different Parts of the EARTH.

WE have ſhewn how the various *Phænomena* of the Tranſit may be computed and eſtimated by PROJECTION and CALCULATION; but there remains yet the moſt natural and genuine Method for aſcertaining the ſame, which is by means of the PARALLAX; and as it has not yet been conſidered and applied for this Purpoſe *(more aſtronomico)* we ſhall here explain that uſeful Doctrine to the Tyro in Aſtronomy.

For this Purpoſe it will be proper for him to have before him a CELESTIAL GLOBE, as he will that Way have a more clear and eaſy Idea of all the fundamental Principles of this Part of the Science, and which are repreſented in Figure 3. Plate III. Where H Z O N is the general *Meridian*; P the North *Pole*; Æ K the *Equinoctial*; T S L the *Ecliptic*, whoſe Pole is Q; C S V the *Orbit* of VENUS; S the *Place* of the SUN, very near the *aſcending Node*; P S B an *Hour-Circle*; Z S N a *vertical Circle*; Q E S a *Circle* of *Latitude*; Q Z G another paſſing through the Zenith Z, and *Nonageſima* Degree G; and Q I another paſſing through the Pole P, to the Beginning of *Cancer* at I.

This is the Poſition of the Globe and its Circles, for repreſenting the *Moment of the End* of the Tranſit, as viewed at LONDON; and therefore the Angle $ZPS = 3^h : 17' = 49° : 15'$. Alſo the Side $ZP = 38° : 30'$, and $PS = 67° : 17'$ the *Co-Declination of the Sun*, whence the Angle PSZ is found to be $45° : 43'$.

Then in the Triangle Q S P there are known all the Sides, P Q = 23° : 30′, P S = 67° : 17′; S Q a Quadrant, and the Angle P Q S = 14° : 24′, the Diſtance of the *Sun* from *Cancer* = I S. Whence the Angle P S Q is found to be 6° : 10′; meaſuring the Inclination of the Circles of Latitude and Declination, or of the Ecliptic to a Parallel of the Equator, as mentioned in Page 18. of the *Diſſertation*.

If from the Angle P S Z = 45° : 43′, we take the Angle P S Q = 6° : 10′, there will remain the Angle E S Z = 39° 33′, the Complement of which is the Angle Z S G = 50° : 27′, which meaſures the Inclination of the vertical Circle Z S to the Ecliptic T S, at their Interſection in the Sun's Center S.

In the laſt Place, ſay, as the Sine of the Angle Z S P = 45° : 43′ is to the Sine of the Side Z P = 38° 30′, ſo is the Sine of the Angle Z P S = 49° : 15′ to the Sine of the Side Z S = 41° : 12′; the Complement of which is the *Sun*'s Altitude at the End of the Tranſit, *viz.* S M = 48° : 48′.

Now we have elſewhere ſhewn (*Inſtitution* 1899 in the GENERAL MAGAZINE) that the horizontal Parallax of a Planet is to its Parallax at any Altiude S M as Radius to the Sine of the apparent Diſtance Z S, from the Zenith Z. If then (with Dr. *Halley*) we ſuppoſe the ſolar Parallax to be 12″ ½, the *horizontal Parallax* of *Venus* will be 45″ nearly (Page 6.); therefore ſay, as Radius to the Sine of Z S = 41° : 12′, ſo is 45″ to 30″ nearly.

When we conſider how ſmall a Part of theſe Circles of *Latitude*, *Altitude*, *Ecliptic*, *Orbit* of *Venus*, &c. are contained on the *Sun*'s Diſk at S, there will be no Difficulty of conceiving that they may be very well repreſented by right Lines on the *Sun*'s Diſk, tho' drawn of any Size you pleaſe; therefore let the ſolar Diſk (Figure 4.), as viewed in the Heavens at the End of the Tranſit, be repreſented by the Circle Z L N T, and thereon draw Z N for the Vertical, E R for the Circle of Latitude, making therewith an Angle E S Z = 39° : 33′; and T S L for the *Ecliptic*, making an Angle Z S L = 50° : 27′, as before found; then ſince E R is perpendicular to T L, if we divide S R into 16 equal Parts or Minutes; or more truly 951 Seconds, and therein take S G = 9′ : 51″ = 591″, and thro' that Point draw the right Line P Q, to contain an Angle S G P of 81° : 32′ with S R, it will truly repreſent the Path of *Venus* over the Face of the *Sun* at her next Conjunction, as ſeen from the Center of the Earth.

But *Venus* ſeen in the *Sun* from the Surface of the Earth, will appear to deſcribe a different Path, by reaſon of the Parallax which will depreſs her to all who live *Northward*, and elevate her above the Line P Q, to all who are *Southward* of the Parallel which the *Sun* that Day deſcribes.

From what has been ſaid, it is alſo evident, that in ſo long a Time as the Planet takes in paſſing through the Chord P Q, the *Sun* muſt every Moment vary its Altitude, and that therefore the Parallax will be conſtantly altering likewiſe. So that ſuppoſing the Center of the Planet upon the *Sun* at C when he is in the Horizon (Figure 4.); then if C D be drawn parallel to Z N the Vertical, it will be equal to the *horizontal Parallax* of the Planet; or, in the preſent Caſe of *Venus*, we have C D = 45″; by the Time the Planet is advanced to the Conjunction at G, the *Sun* is riſen to a certain Altitude, and the Parallax thereby diminiſhed. Laſtly, By the Time the Planet is advanced to (*c*) at its Egreſs from the *Sun*, the *Sun*'s Altitude will be farther increaſed, and the Parallax proportionably diminiſhed; and therefore drawing a Line through the Points C, *c*, it will be the *viſible Path* of the Planet over the *Sun*, every-where at an unequal Diſtance from the true one P Q.

The two ſmall Lines C D, and c d, being drawn parallel to the Vertical Z N, will be the Parallax, at the Beginning and End of the Tranſit; and thoſe two Lines are each of them reſolvable into two others; *viz.* C F, F D, and c f, f d; the firſt of which, in each Caſe, is perpendicular to the true Path; and the other parallel to it; and therefore at the ſame Time that the Parallax in Altitude C D, c d, depreſſes the Planet from its true Places D, d, to the viſible Places C, c, it carries it backwards in its Path from D to F at the Beginning, and from d to f at the End of the Tranſit. And as the Motion from D to F, as alſo from d to f, is directly contrary to the Motion of the Planet in its Path, it *retards* the Time of its *coming on* and *going off* the Solar Diſk.

What this Time is, may be found by computing the Quantity of the Lines D F, or d f. Thus for Example; let (*c*) be the Center of *Venus* at the Time that ſhe touches the *Sun*'s Limb internally at O; ſo that drawing S c O, we have c O equal to *Venus*'s Semidiameter, or 37″ ½; and S O=914″. Draw S M perpendicular to the Path P Q, biſecting it in H, then is the Angle M S R = 8° 28′, which taken from N S R = F S Z = 39° 33′, there will remain the Angle N S M = 31° 05′. Now this Angle is equal to the Angle F c d; for f c is parallel to M S, and c d is parallel to S N.

Therefore, in the Right-angled Triangle c f d, there is given the Angle f c d = 31° 05′; and the Hypothenuſe c d = 30″, which is the Parallax at 41° 12′, the Altitude of the *Sun* at that Time. Then ſay, as Radius to 30″, ſo is the Sine of 31° : 05′ to 15″ ½ = f d. Now ſince *Venus* moves at the Rate of 240″ per Hour, or 60′ = 3600″, if we ſay, As 240″ of Motion is to 3600″ of Time, ſo is 15″ ½ of Motion to 232″ ½ of Time, which is 3′ 52″ ½, by which the Egreſs is retarded by the *Parallax in the Path*. After the ſame Manner, if the Beginning of the Tranſit were viſible at *London*, the Quantity of F D might be computed for the *Sun*'s Altitude when the Planet enters the Solar Diſk, and thence the Time by which it would be retarded; or how much later it would happen at LONDON than if ſeen from the *Earth*'s Center.

Beſides the Effect of the Parallax upon the Motion of the Planet in its Orbit, it has another, which very much affects the Time of the Duration of the Tranſit, by diminiſhing or increaſing the Chord or Path on the Diſk. In the preſent Caſe, to us at *London* the Planet is depreſſed from the Chord P Q to the Chord V W; on the Center S, through the Point (*c*), ſweep the ſmall Arch a c b, interſecting the Chord P Q in the Point (*a*); then ſince K c is leſs than H a by the Quantity f a, it is evident, that on this Account the *Phænomena* of the Egreſs will be accelerated, or they will happen ſooner in the *viſible Path*, as viewed from *London*, than in the *true Path*, as ſeen from the Center of the *Earth*, by all the Time the Planet takes to paſs over the Space f a.

This Line f a is therefore to be computed; in the Right-angled Triangle G S H, we have S G = 591″, and the Angle H S G = 8° 28′, whence we find S H = 584″ ½. Again, in the ſmall Triangle f c d, we find c f = 25″ ½; then S H + f c = S r = 610″; then in the Right-angled Triangle S r c, there are two Sides, S c and S r known, whence we find the Angle S c r = S e H = 41° 55′, and H S e = 48° 05′.

Then, becauſe the Right-angled Triangles H S e, e c a, and c f a, are ſimilar, the Angles in the laſt are known, whence we find the Side f a = 23″; but 240″ per Hour is 1″ in 15″ of Time;

therefore $23 \times 15 = 305'' = 5' : 5''$ of Time in which *Venus* will paſs over the Space f a, by ſo much therefore will the Egreſs be accelerated; but we have ſhewn it is retarded by the Parallax in the Path by $3'\ 52''$. Whence $1'\ 13''$ is the Time by which the Egreſs at *London* is accelerated.

In the ſame Manner you proceed for calculating the Times of paſſing over F D and A F in the Beginning of the Tranſit, where viſible; and you will eaſily obſerve, if both Parts accelerate, or both retard, the Time of the Beginning or End of the Tranſit, or whether they are contrary to each other in that Reſpect. Thus for example, in the preſent Caſe, the Parallax in the Path F D, and that in the Perpendicular, which ſhortens the Path by the Space A F, both retard or contract the Tranſit at the Beginning; but at the End the Effect of one is contrary to that of the other, as we have ſhewn.

In the Caſe before us, the Beginning and End of the Tranſit happen in the Forenoon; but when they happen in the Afternoon, the Part of the Parallax denoted by F D, f d, accelerates the Time of the Beginning and End of the Tranſit, by cauſing the Planet to appear to come on and go off from the *Sun* ſooner than it really does: The Reaſon of which is very obvious, with a little Reflection; eſpecially if a Scheme be conſtructed like that in Figure 2. on the Weſtern Side of the Globe, for any Place where the Tranſit will begin and end in the Afternoon.

It is evident from this Theory, that though the Beginning and End are both retarded, or both accelerated, when they happen before or after Noon; yet they are very unequally ſo: For the Beginning is retarded by both Effects of the Parallax; *viz.* F D and A F; but the End is accelerated only by their Difference d a. And thus the Beginning is accelerated by the Sum F D + F A in the Afternoon, and the End by the Difference f a — f d.

Therefore, in order to have the Duration of the Tranſit contracted as much as poſſible, the Obſervations ſhould be made in thoſe Places where the Beginning is before Noon, and End after; as in moſt Parts of the *Eaſt Indies*.

The Places ſhould be ſuch alſo as have the Beginning and End at the ſame Diſtance of Time from Noon, or at equal Altitudes of the *Sun* before and after Noon; becauſe the Sum of the Parallaxes of two equal Altitudes being as the Sum of the Co-Sines of thoſe

Altitudes, will be greater than the Sum of the Parallaxes of two unequal Altitudes of the ſame Number of Degrees. Thus twice the Sine of 45 Degrees from the Zenith is greater than the Sum of the Sines of 60 and 30 Degrees, as you may ſee in the Tables.

What we have now ſaid relates to the Parallax F D and f d, in the Path; but then, ſince at a given Altitude the abſolute Parallax D C (= d c in equal Altitudes) is a conſtant Quantity, the Angle F C D muſt be ſuch, that the Sum F D + A F = A D, ſhall be the greateſt poſſible. It is evident that when *Venus*'s Path P Q coincides with the Vertical Z N, we have A F = 0; and when it is perpendicular to the ſame, then F D = 0, and A F = C D; and it is eaſy to underſtand, that when a given Line D C is to be adapted in a given Angle C A D, ſo as to make A D a Maximum, the Angle D C A muſt be a *right one*; and therefore the Latitude of the Place ſuch, that the Vertical Z N ſhall paſs through the Center of the Planet C at the Moments of her internal Contact, at the Beginning or End of the Tranſit, which may eaſily be determined from the Principles above laid down.

For in this Caſe, the Angle N S M will be equal to the Angle M S O, which is 48° 05′, as we have ſhewn. Then if to this we add the Angle M S R = 8° 28′, it will make the Angle R S N = 56° 33′, which will be the Angle E S Z in Fig. 3. Then laſtly, if to this you add the Angle E S P = 60° 10′, you will have the Angle Z S P = 62° 43′; and ſuppoſing the Tranſit to begin and end at 3^{h} 15′ from Noon, the Angle Z P S will be 48° 45′, then in the Triangle Z S P there are two Angles, and the Side S P known, to find the Side Z P, which will be 55° 10′, and therefore Æ Z = 34° 50′, the Latitude ſought, where the Quantity A F + F D (Fig. 4.) will be the greateſt poſſible.

THE USE of the TRANSIT of VENUS

In INVESTIGATING the ELEMENTS of her THEORY,

Explained and Exemplified from the OBSERVATIONS of Mr. HORROX.

THE firſt and moſt celebrated of Obſervations reſpecting the Planet *Venus*, is that of her Paſſage over the *Sun*'s Diſk, which was obſerved at *Hoole*, near *Leverpool*, in *Lancaſhire*, by our Countryman Mr. *Horrox*, on the 24th of *November*, in the Year 1639; of which we have a particular Account in his Book afterwards publiſhed by *Hevelius* in 1673, intituled *De Venere in Sole Viſa*. The *Sun* being then nearly ſetting in the Horizon, he prepared himſelf to make Obſervations thereon in a darkened Room, by taking his Image upon a proper Skreen, and which we have here repreſented by a Circle TELR (Fig. 5. Plate III,), and being provided with proper Inſtruments to meaſure the ſeveral Parts, he obſerved her to be wholly within the Diſk, and then to touch the *Sun*'s Limb internally at A, at 15 Minutes after III. The Diſtance between the Center of the Planet V and that of the *Sun* S, he found to be $14' 25''$, reckoning the Minutes ſuch that the Diameter of the *Sun* contained $30'$, and that of the Planet $1' 10''$.

The ſecond Obſervation was made at 35 Minutes after III. and the Diſtance he then found between *Venus* and the *Sun* to be $13' 30''$. And by a third Obſervation, at 45 Minutes after III, he found the Centers of *Venus* and the *Sun* to be juſt 13 Minutes apart; and the *Sun* ſetting at 50 Minutes after III, put an End to any further Obſervations.

From thoſe few and imperfect Obſervations, *Horrox* proceeded to find the preciſe Time of the Conjunction of *Venus* with the *Sun*, and other Elements of Theory, in the following Manner: He ſuppoſed the *Sun*'s Place to be in ♊ 12° 24′, and having calculated the Angle A S T (in the Manner we have ſhewn from Fig. 3. 4.) or the Diſtance of the Point A from the Ecliptic T, which he found to be 46° 34′, whoſe Complement A S R, the Diſtance between *Venus* and the Circle of Latitude E R, is 43° 26′; and having ſuppoſed the Diameter of the *Sun* to be 31′ 30″, and that of *Venus* 1′ 16″ (reckoned of the uſual Magnitude) he found the Diſtance between the Centers S V to be 15′ 7″, and from thence the Difference of Longitude V C to be 10′ 24″, and her Difference in Latitude V H 10′ 58″.

As theſe Differences of Latitude and Longitude were only apparent, and as *Venus* was at that Time nearly in the Horizon, her Parallax by which ſhe was depreſſed, was nearly equal to the Horizontal Parallax, which he made to be 52″, ſuppoſing that of the *Sun* to be 14″, the Difference of which is 38″ for the Parallax of *Venus* from the *Sun*.

Thro' the Point V draw the Right Line V O parallel to the vertical Circle Z N, and equal to 38″, which was the Parallax of *Venus* from the *Sun*; then drawing the Line O c parallel to V c, and O h parallel to V H, there will be formed the Right-angled Triangle V O I, in which the Side V O and the Angle at V are known (from what we have before delivered), and from thence he found the Side I V, which was the Parallax in Latitude, to be 36″, and the Side I O to be 13″ in Longitude; ſo that the true Latitude of the Planet was S c, and the true Longitude S h. He likewiſe calculated, in the ſame Manner, the Difference of Latitude and Longitude for the other two Obſervations; ſo that, for the three Obſervations, the apparent and true Latitudes and Longitudes were as in the following Tables:

	True Long.	Ap. Long.	True Lat.	Ap. Lat.
At 3^{h} 15′	10′ 37″	10′ 24″	10′ 22″	10′ 58″
3 35	9 36	9 22	10 3	10 38
3 45	9 5	8 51	9 49	10 24

Now from hence to find the Time and Place of the true Conjunction of *Venus* with the *Sun*, our Author ſuppoſed that the *Sun*'s daily Motion was 1° 1′ 2″, and that of *Venus* retrograde to be 36′

38″, whence the Sum 1° 37′ 40″ meaſures the apparent Motion of *Venus* in Regard to the *Sun* in the Space of 24^{h}; and therefore he uſed the following Analogy: As 1° 37′ 40″ is to the Difference of Longitude between the Center of the *Sun* and *Venus* 10′ 37″, ſo is 24^{h} to 2^{h} 36′ 30″; which added to 3^{h} 15′, the Time of the firſt Obſervation, gave the Time of the true Conjunction of *Venus* with the *Sun* to be at 5^{h} 51′ 30″ on the 14th of *November*, 1639.

From the Firſt, compared with the Second and Third Obſervations, he found the Time of the Conjunction to be at 5^{h} 56′ 30″, and 5^{h} 59′, and taking the Mean of all, he found it to be 5^{h} 55′ for the Time of true Conjunction, and for that Time having calculated the *Sun*'s Place in ♐ 12° 29′ 35″, he found, of courſe, the Place of *Venus* to be in the oppoſite Sign *Gemini* 12° 29′ 35″.

Having calculated the apparent Latitude of *Venus* in the Space of 24^{h}, which he found to be 15′ 40″, he took the proportional Parts correſponding to 2^{h} 40′ (the Time between the firſt Obſervation and Conjunction) and found it to be 1′ 44″, which having deducted from the true Latitude of *Venus* obſerved at the Time of the firſt Obſervation, there remained 8′ 38″ for the Latitude at the Conjunction; and by the other two Obſervations he found the ſame Latitude to be 8′ 32″ and 8′ 24″; and taking the Mean of all the three, he found it to be 8′ 31″.

In the next Place, to determine the Place of the Node, Mr. *Horrox*, from the given Diſtance of the Planet from the *Earth* and the *Sun*, and the Geocentric Latitude of *Venus* 8′ 31″, he found the Heliocentric Latitude to be 3′ 7″, and then ſuppoſing the Inclination of the Orbit of *Venus* to the Ecliptic to be 3° 22′, he found by Calculation (in the Manner we have before ſhewn) the Diſtance of the Planet from the Node at the Time of Conjunction to be 53′ 10″, which being added to the true Place of *Venus* which was before found in *Gemini* 12° 29′ 25″, it gave the true Place of the Node in *Gemini* 13° 22′ 45″, but very little different from the Place where *Kepler* had before found it, *viz.* only 1′ 32′.

Such is the Method by which Mr. *Horrox* attempted to ſettle the Elements of the Theory of this Planet; but having herein aſſumed the Diameter and Place of the *Sun*, alſo their Horizontal Parallaxes, different from what they are now found to be, this Theory was afterwards corrected by Mr. *Caſſini*, and the true Latitude and Longitude for the Times of the Obſervations reduced to the Meridian of *Paris*, as in the following Table:

		True Long.	True Lat.
At 3ʰ 37′	at *Paris*	10′ 56″ 1/3	10′ 58″ 3/4
3 57		9 53	10 36 1/2
4 7		9 20 5/6	10 21 2/3

By theſe true Differences of Latitude and Longitude he found the Time of the true Conjunction at *Paris* to be four Minutes after VII, and the true Place of *Venus* to be in *Gemini* 12° 33′ 36″.

Mr. CASSINI's METHOD,

For DETERMINING the foregoing

ELEMENTS of VENUS's THEORY.

MR. *Caſſini* having conſidered, that, in the Space of Half an Hour, the Motions of *Venus* in Latitude and Longitude were too little ſenſible for deducing the Elements of her Theory from thence, with ſufficient Preciſion, he purſues another Method for that Purpoſe, on Suppoſition that the Ratio of the Diſtances of *Venus* from the *Sun* and the *Earth* is known; as alſo the Inclination of her Orbit, and the Quantity of her true Motion ſeen from the *Sun*.

He calculates the Place of the *Sun* in ♊ 12° 24′ 52″, and ſuppoſes the Diameter of the *Sun* 32′ 40″, and the ſolar Parallax 10″; then he proceeds to the Computation. The Longitude of *Venus* at the Time of the firſt Obſervation having been determined 10′ 56″ 1/3, and her Latitude 10′ 58″ 3/4; ſay, As the Diſtance of *Venus* from the *Sun* 72008, is to the Diſtance of *Venus* from the *Earth* 26522, ſo are 10′ 56″ 1/3 to 4′ 2″, which meaſures the Difference of Longitude between *Venus* and the *Earth*, ſeen from the *Sun* at the Time of the firſt Obſervation, and which being deducted from the true Place of the *Earth*, which was then in ♊ 12° 24′ 52″, gives the true Place of *Venus* in ♊ 12° 20′ 50″, on the 4th of *December* 1639, at 33 Minutes after III. the true Time at *Paris*, New Stile.

In like manner ſay, as 72008 is to 26522, ſo are 10′ 58″ the Latitude of *Venus* ſeen from the Earth to 4′ 3″, which meaſure the Latitude of *Venus* ſeen from the *Sun* at the Time of the firſt Obſervation.

In like manner for the ſecond Obſervation, *viz.* 35 Minutes after III. the true Time, her Place was found to be in ♊ 12° 22′ 5″, and her heliocentric Latitude 3′ 54″ ½. Laſtly, For the Time of the third Obſervation, her Place in ♊ 12° 22′ 40″, and her Latitude 3′ 49″.

The Latitude of *Venus* being thus found at the Times of the three Obſervations, we find the Place of the Node by the following Analogy. As the Tangent of the Inclination of the Orbit 3° 23′ 20″ is to Radius, ſo is the Tangent of the heliocentric Latitude of the firſt Obſervation 4′ 3″, to the Sine of the Diſtance of *Venus* from the Node 1° 8′ 37″.

By the ſame Analogy it is found, at the Time of the ſecond Obſervation, to be 1° 6′ 13″, and at the Time of the Third 1° 4′ 39″; and adding theſe to the true Place of *Venus* ſeen from the *Sun*, we ſhall have the true Place of the Node, by the firſt Obſervation, in ♊ 13° 29′ 27″, by the Second in 13° 28′ 18″, and by the Third 13° 27′ 19″; and taking a Mean of the three, we have the true Place of the Node in *Gemini* 13° 28′ 21″ farther advanced by 6 Minutes than her Place determined by *Horrox*.

In order to find the Time and Place of the true Conjunction of *Venus* with the *Sun*, and her Latitude, we muſt conſider that her daily Motion was then 1° 36′ 44″, from which we muſt ſubſtract the Motion of the *Sun* in 24^{h}, *viz.* 1° 1′ 0″, and there will remain the Motion of *Venus* from the *Earth*, as viewed from the *Sun*, 35′ 44″ *per Diem*. Then ſay, as 35′ 44″ are to 4′ 2″, ſo are 24^{h} to 2^{h} 43′, which being added to 3^{h} 37′ (the Time of the firſt Obſervation) gives the Time of the Conjunction of *Venus* with the *Sun* 6^{h} 20′, true Time at *Paris*; which reduced to the Meridian of *Leverpool*, will be 5^{h} 58′, which is 3 Minutes later than the Time of Conjunction determined by *Horrox*; and calculating for the ſame Time, the true Place of the *Sun*, which is the ſame with that of *Venus*, it will be found in ♐ 12° 31′ 44″, the oppoſite

Point to which is *Gemini* 12° 31′ 44″, which being deducted from the Place of the Node (before found) in *Gemini* 13° 28′ 45″, we ſhall have the Diſtance of *Venus* from her Node at the Time of her Conjunction with the *Sun* 57′ 1″, by which we ſhall find her heliocentric Latitude to be 3′ 22″, and her Latitude ſeen from the *Earth* 9′ 8″, larger by only 37″ than that which was determined by *Horrox*.

Theſe are the general Methods by which the Theory of *Venus*'s Motion may be aſcertained, and in a great meaſure ſettled, by numerous and accurate Obſervations made on the apparent Diſtances between the Centers of *Venus* and the *Sun* at the next enſuing Tranſit, which may be very eaſily meaſured by means of a proper HELIOMETER, ſo conſtructed that it ſhall give the true Poſition of the Ecliptic, with reſpect to the vertical Circle, for any given Moment of Time during the Tranſit, as alſo the apparent Latitude from the Ecliptic through the whole Duration.

We ſhall only add, that the Reaſon why *Venus* appears no oftener in the Face of the *Sun* is, becauſe that when her Diſtance from the Node is about 2 Degrees, her Latitude ſeen from the *Sun* is about 7′ 5″, which Latitude, viewed from the *Earth*, will make 16 or 17 Minutes, and therefore exceed the Semi-diameter of the *Sun*. When ſhe exceeds this ſmall Diſtance from the Node, ſhe will paſs above or below the *Sun*'s Diſk, and may be obſerved in thoſe Conjunctions to have ſome Part of her enlightened Diſk turn towards the Earth; more and more, in Proportion as ſhe approaches the *Nonageſima* Degree of her Orbit; to which when ſhe arrives, the Portion of her enlightened Surface will be the greateſt of all, and equal to the Sum of her greateſt and leaſt heliocentric Latitude.

For ſuppoſe P (Figure 6.) to be the Place of the Planet in that Situation in her Orbit B D, let S be the Center of the *Sun*, and T that of the *Earth*; and through the Center of the Planet P draw the right Lines S K and T H, then will A C, a Part of the Orbit, be perpendicular to S K, and conſequently determine the enlightened Hemiſphere of the Planet A I G. Then draw C F parallel to T H, and it will cut off the Arch A C of the enlightened Hemiſphere, for that Part which can be ſeen at the *Earth*; and becauſe the Arch A I and C E are each 90 Degrees, and the Arch C I common to both; if that be deducted from the other two, it will leave the Arch A C equal to the Arch E I: but the Angle E P I is equal to the Sum of the two internal Angles at T and S, or the Sum of the greateſt heliocentric and geocentric Latitudes together; which therefore is equal to the Part of the enlightened Surface of the Planet A C turned towards the *Earth*.

To conclude; in caſe the Morning ſhould prove cloudy, and we are thereby prevented from viewing the Riſing-Sun with *Venus* on his Diſk, I thought it might not be unacceptable to have an Idea thereof communicated by a Diagram (ſee Figure 7.); where H O repreſents the eaſtern Part of the Horizon, in which the *Sun* will riſe. A D is a Part of the Ecliptic, deſcribed by the *Sun*'s Center making an Angle with the Horizon of about 26 Degrees. A is the Poſition of the *Sun* below the Horizon, when its upper Limb juſt touches the Horizon in B. C the Center of the *Sun* juſt in the Horizon; and D its Poſition when the lower Limb juſt touches the Horizon in E, or the *Sun* is wholly riſen above it. The Time in paſſing from A to D, or riſing wholly above the Horizon, is a little more than four Minutes. The Path of *Venus* on the *Sun* is repreſented by (*a b*), and the Planet itſelf by a Black Spot, as far advanced on the *Sun*'s Diſk at his Riſing, as is here repreſented.

N.B. *What further relates to the Tranſit of* Venus *is fully explained in two large* Copper-Plate PRINTS, *viz. one of ſeventeen Tranſits of this Planet over the* Sun's *Diſk; the other of three* Geographical *Projections for the Time of the* BEGINNING, MIDDLE, *and* END *of the* TRANSIT *in every Part of the World; with the Uſes thereof explained.*

FINIS.

ERRATA.

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PAGE 4. for N $d\times\frac{b}{a}$ read N : $d\times\frac{b}{a}$

6. the Micrometer, *r.* a Micrometer.
9. of South, *r.* South.
13. of the, *r.* on the.
ibid. Parallax of 22° : 30′, *r.* Parallel of 22° : 30′.
ibid. ſooner at *b*, r. later at *b*.
17. apparent Motion of the Nodes, *r.* true Motion of the Node.

The THEORY of VENU

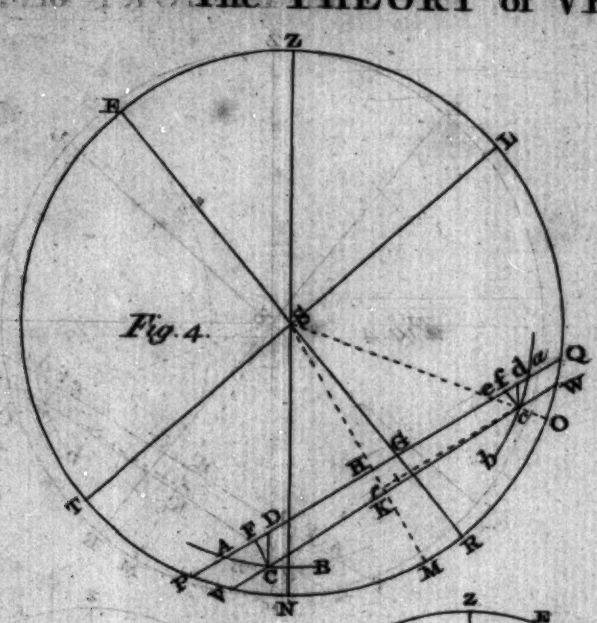


Fig. 4.

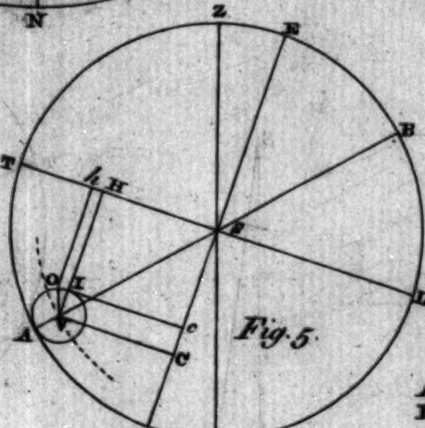


Fig. 5.

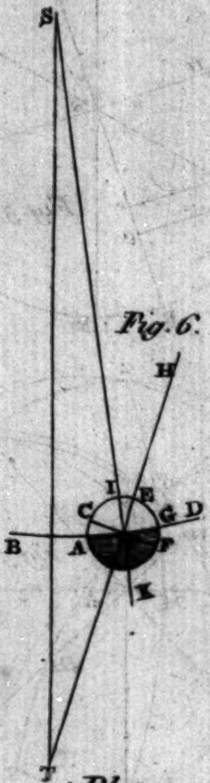


Fig. 6.

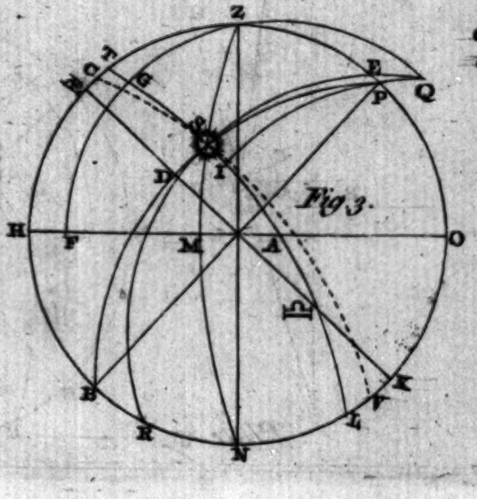
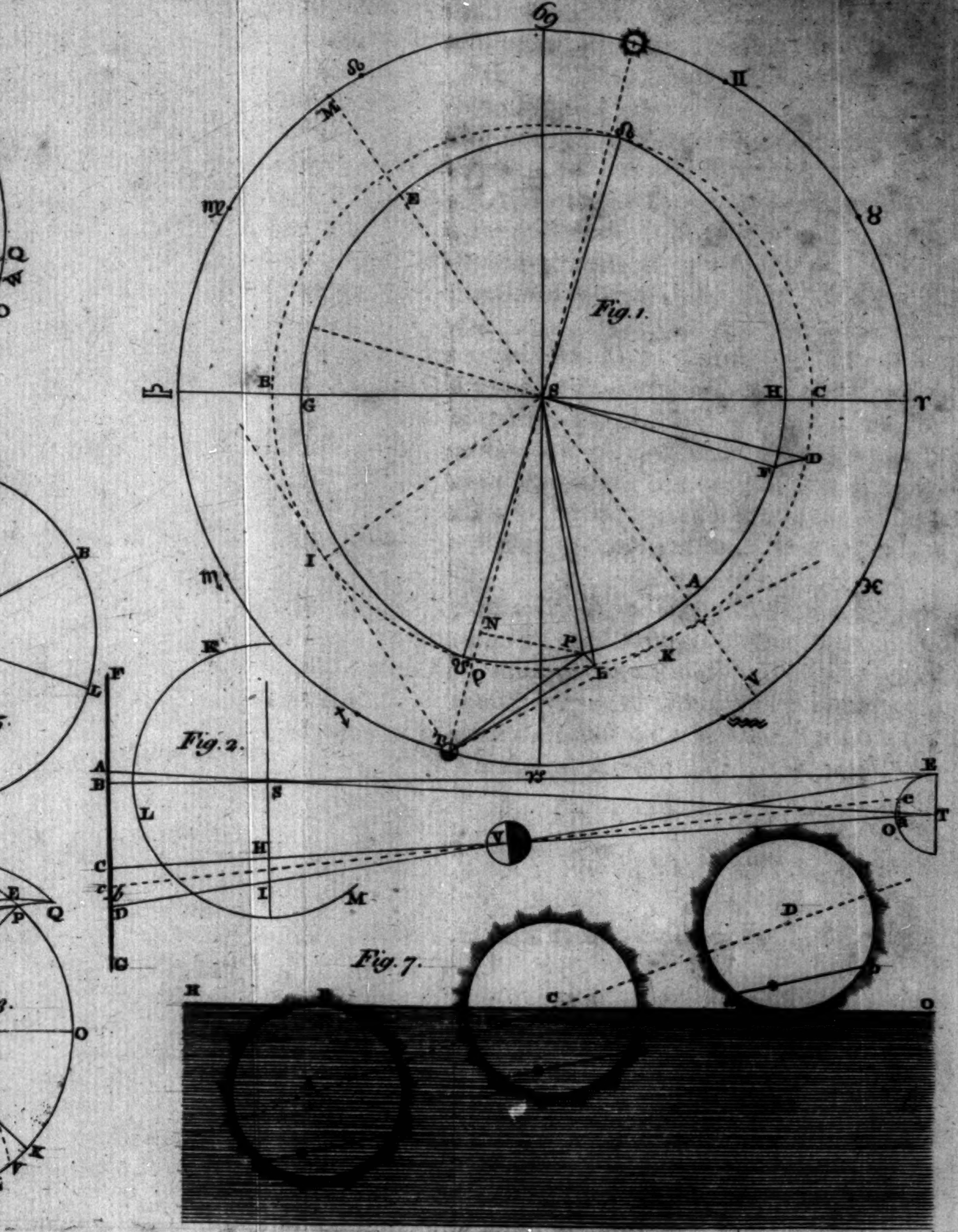
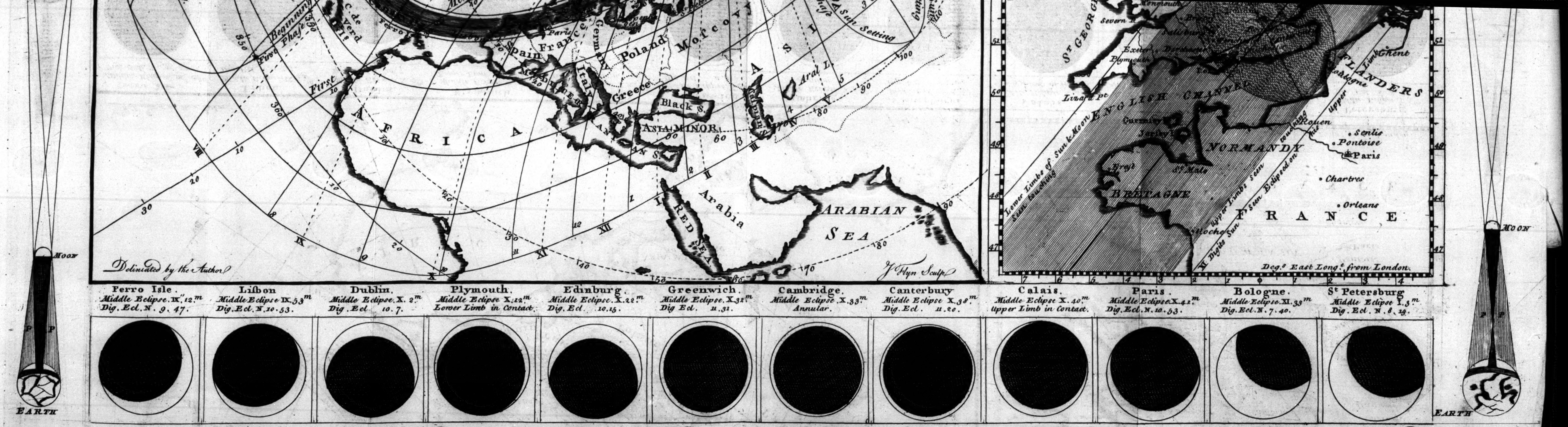


Fig. 3.

Plate III.

VENUS'S MOTION PARALLAX & other Phænomena.





Ferro Isle. *Middle Eclipse. IX. 12m Dig. Ecl. N. 9. 47.*

Lisbon *Middle Eclipse IX. 53m Dig. Ecl. N. 10. 53.*

Dublin. *Middle Eclipse. X. 2m Dig. Ecl. 10. 7.*

Plymouth. *Middle Eclipse X. 12m Lower Limb in Contact.*

Edinburg. *Middle Eclipse. X. 22m Dig. Ecl. 10. 15.*

Greenwich. *Middle Eclipse. X. 32m Dig Ecl. 11. 31.*

Cambridge. *Middle Eclipse. X. 33m Annular.*

Canterbury *Middle Eclipse X. 38m Dig. Ecl. 11. 20.*

Calais. *Middle Eclipse X. 40m Upper Limb in Contact.*

Paris. *Middle Eclipse X. 41m Dig. Ecl. N. 10. 53.*

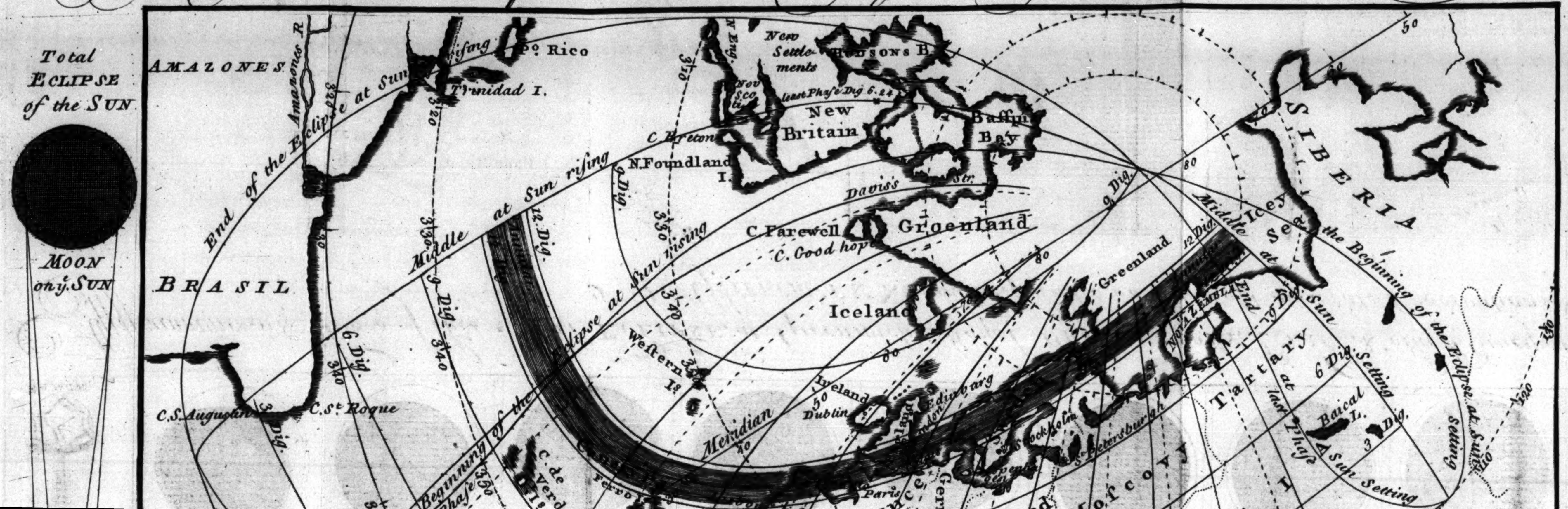
Bologne. *Middle Eclipse. XI. 33m Dig. Ecl. N. 7. 40.*

St Petersburg *Middle Eclipse I. 3m Dig. Ecl. N. 8. 19.*

Appearances & Times of this Solar ECLIPSE, at Greenwich Royal OBSERVATORY, London, & other Principal CITIES, & Remarkable PLACES. Computed by Tables in The Royal Aſtronomer & Navigator, founded on the moſt accurate Observations, & NEWTONIAN Principles of Gravity.

A General and Particular MAP of the Paſsage of the MOON'S SHADE, or PENUMBRA, over y^e Earth, in the Solar ECLIPSE, April, 1^{st} 1764

A View of the Boundaries of the EARTH, from where the SHADE first enters thereon, to where it quits the EARTH in its Paſsage over it. In which the MOON'S whole Body appears on the SUN, touching His Edge, with a Ring of Light quite round the MOON. Likewise shewing the BOUNDAIRES of the Earth, where the SUN appears ECLIPS'D, to every 3 DIGITS, on each Side of the Central Shade. With the Limits of the Beginning, Middle, and End of the Eclipse, at Sun Rising & Setting.



A View of the PASSAGE, Direction, BREADTH, Boundary, stated Velocity, of the MOON'S SHADE over England, & Parts Contiguous.